Sustainability of Rural Water Services in Low-Income Countries: Case studies in sub-Saharan Africa

by

Peter A. Harvey

A submission presented in partial fulfilment of the requirements of the University of Glamorgan/Prifysgol Morgannwg for the degree of Doctor of Philosophy

September 2008

Contents

Dedication

I wish to dedicate this PhD submission to the memory of my grandfather Stephen Joyce Price (1910-2003), an intellectual inspiration, and my mother Julia Harvey (1943-2007) who always had faith in me. May they rest in peace.

Acknowledgements

I would like to thank my Director of Research Dr. Linus Mofor and Supervisor Dr. John Kinuthia for their support, guidance and encouragement during the preparation of this research publications submission.

I would also like to thank the Department for International Development (DFID) of the British Government, which supported a significant proportion of the research work through the Knowledge and Research (KaR) project 'Guidelines for Sustainable Handpump Projects in Africa' (R7817), conducted by the Water, Engineering and Development Centre (WEDC), Loughborough University. Opinions noted within this submission do not necessarily represent those of DFID or WEDC but are solely those of the author.

R11

Certificate of Research

This is to certify that, except where specific reference is made, the work described in this thesis is the result of the candidate's research. Neither this thesis, nor any part of it, has been presented, or is currently submitted, in candidature for any degree at any other University.

Signed ....
Candidate

Date ......22:9:08......

Signed ....
Director of Studies

Date ......22-09-08......

Abbreviations

AF	Annuity Factor
CBO	Community Based Organisation
CPA	Comparative Performance Analysis
CWSA	Community Water and Sanitation Agency (Ghana)
DFID	Department for International Development (UK)
DWD	Directorate of Water Development (Uganda)
GAP	Greater Afram Plains
GATS	General Agreement on Trade and Services
GRWP	Ghana Rural Water Project
GSB	Ghana Standards Board
HIPC	Highly Indebted Poor Countries
IDS	Institute for Development Studies
IMF	International Monetary Fund
KaR	Knowledge and Research
MDG	Millennium Development Goal
MLGH	Ministry of Local Government and Housing (Zambia)
MoF	Ministry of Finance
MWR	Ministry of Water Resources (Kenya)
NAO	National Audit Office
NGO	Non-Governmental Organisation
ODI	Overseas Development Institute
O&M	Operation and Maintenance
PPCC	Probability plot correlation coefficient
PPOM	Public-Private Operation and Maintenance
PRS	Poverty Reduction Strategy
PRSP	Poverty Reduction Strategy Paper
ROSCA	Rotating Savings and Credit Association
RWSN	Rural Water Supply Network
SDB	System Density Breakpoint
UNBS	Uganda National Bureau of Standards

UNDP	United Nations Development Program
UNICEF	United Nations Children's Fund
VAT	Value Added Tax
VLOM	Village Level Operation and Maintenance
WASHE	Water, Sanitation and Hygiene Education
WEDC	Water, Engineering and Development Centre
WHO	World Health Organisation
WSP	Water and Sanitation Program

Structure of submission

This PhD by publications submission, in accordance with the University's guidelines, comprises the following:

- An abstract;
- A critical overview outlining the background to the research, the aims and objectives, research methodology, research synthesis (including a summary of each publication), conclusions and recommendations;
- Six refereed academic journal papers and one peer-reviewed conference paper;
- List of references for critical overview;
- List of publications submitted in an Appendix.

Abstract

Access to adequate water and sanitation is fundamental to enhancing the quality of life for rural populations. Over the past few decades substantial amounts of money have been spent and efforts made to provide rural water supply services in various developing countries. However, the provision of such services to date is largely unsustainable and it is unlikely that the Millennium Development Goal target for safe drinking water in rural areas will be met. This is particularly so in sub-Saharan Africa, which has the lowest coverage of water services in the world. The question, therefore, is why, despite all the monies spent and efforts made, is the sustainability of rural water services in low-income countries currently poor, especially in sub-Saharan Africa, and what can be done to improve this situation? The papers on which this research submission is based used selected case studies of countries in sub-Saharan Africa to critically evaluate and assess the key factors contributing to this state of rural water supply services. This was achieved through (i) content analysis of rural water supply policy documents from a range of sub-Saharan African countries; (ii) community sampling, focus group discussions and key informant interviews in several countries; (iii) comprehensive review of management models implemented across the sub-continent; (iv) detailed financial analysis of long-term operational costs for rural water supply systems; (v) assessment of the performance of different rural water supply technologies; (vi) technical analysis of drilling data and water source sustainability; and (vii) analysis of supply chain viability.

The policy analysis revealed a range of common themes that may impact on the sustainability of rural water provision, including decentralisation, privatisation and community management. The community sampling, focus group discussions and key informant interviews in several countries showed that communities require more information from implementing agencies, greater choice in relation to technology and management options, and sustained institutional support. A review of management models implemented across the sub-continent identified the need for greater flexibility in management approaches, and the need to explore alternatives based on sustainable incentives, such as indigenous private sector service delivery. Detailed financial

analysis of long-term operational costs for rural water supply systems revealed that costings are generally insufficient and communities are not provided with sufficient information on financial implications to make informed decisions. Technology performance assessments demonstrated that the rope-pump outperforms the conventional handpump as an appropriate water supply technology for hand-dug wells. It was also demonstrated that the initial measured yield of a borehole is the single largest factor that influences subsequent borehole failure, and that the likelihood of borehole failure increases by a factor of six when drilling occurs during the wet season. Supply chain analysis revealed that stand-alone supply chains for handpump spare parts are commercially unviable in rural sub-Saharan Africa. From the critical evaluation of the outcomes of these studies, it is concluded that in order to achieve truly sustainable rural water supply services greater interconnectedness between technology, environment, supply chains, financing and management is needed within co-ordinated programmes, supported by enabling policies.

1. Critical Overview

1.1 Background to the research

According to the World Health Organisation and the United Nations Children's Fund rural water coverage in Africa was 47% in 2000, compared to 44% in 1990, still leaving 256 million people unserved (WHO/UNICEF, 2000). One of the Millennium Development Goal (MDG) targets agreed at the United Nations in 2000 is to halve by 2015 the proportion of people without sustainable access to adequate and affordable safe drinking water (Annan, 2000). This goal will be much harder to achieve in rural Africa than in the rest of the developing world due to the low levels of existing coverage coupled with high population growth rates. This is further compounded by the fact that existing services demonstrate limited sustainability throughout the continent.

The International Drinking Water Supply and Sanitation Decade (1981-1990), which had as its slogan "Water and Sanitation for All", brought attention to the plight of the rural poor and the need for low-cost simple technologies which communities can afford and maintain with their own resources, since it was apparent that past policies had left a legacy of expensive and non-functioning systems all over the world (Arlosoroff et al., 1987). As a result of the Water Decade, developing countries and donors began recognising the importance of the handpump due to the low cost and ease of operation and maintenance, and the availability of shallow groundwater resources beneath much of Africa and Asia. Wells and boreholes with handpumps were therefore promoted as the most viable option for rural water supply in many developing countries. Groundwater provides potable water to an estimated 1.5 billion people worldwide daily (DFID, 2001) and has proved the most reliable resource for meeting rural water demand in sub-Saharan Africa (Macdonald & Davies, 2000). Consequently, in the past two decades handpumps have become the principal technology for supplying water to over 1 billion people in rural areas in at least 40 developing countries (RWSN, 2004). For this reason, this research has a particular, though not exclusive, focus on handpump-based rural water services.

There are approximately 250,000 handpumps in Africa, of which it is estimated that 35% are non-operational at any given time (Baumann, 2005). This is backed up by data from Malawi (Moss, 2003), South Africa (Hazelton, 2000), Uganda (DWD, 2002), and Zambia (MLGH, 2007), which indicate operational failure rates of between 25% and 52%. Despite this low level of sustainability, handpumps are likely to remain a major method of delivery of rural water supplies, as they are considered the most appropriate and popular solution in many cases. Investment will be short-lived and will make little contribution to achieving the MDG target unless ways can be found to make future rural water supply services more sustainable. This can only be achieved if the problems and factors constraining sustainability are identified, and solutions to these are investigated.

1.2 Aims and objectives

The overall aim of the submitted work is to:

Identify barriers to, and determine strategies to increase, the sustainability of rural water services in low-income countries, using case studies in sub-Saharan Africa.

Specific objectives include to:

- analyse poverty reduction strategy papers to determine potential opportunities for, and threats to, increased rural water service sustainability contained within national policies;
- investigate different institutional and management models and assess the potential for private sector delivery of rural water services;
- determine costs of sustainable operation and maintenance of rural water systems and investigate sustainable financing mechanisms;
- determine whether, and under what conditions, community management contributes to sustainable rural water services, and whether there are alternative solutions that are largely being ignored at present;
- assess the performance of different rural water supply technologies with respect to sustainable operation and maintenance;

- investigate the relationship between rapid-onset failure of groundwater boreholes and available operational field data; and
- assess the sustainability and viability of supply chains for spare parts for rural water systems.

1.3 Research methodology

The first step in the research methodology was to determine the meaning of the term 'sustainability' and identify 'sustainability factors'. An extensive literature review was undertaken to investigate different ways of defining and assessing sustainability. On the basis of this, seven sustainability factors were identified, adapted from the sustainability indicators developed for the UK water industry. These indicators are based on the framework of sustainability capital (developed by the Forum for the Future) comprising the following six themes (Luckhurst, 2003):

- Governance, strategic planning and management;
- People (human capital);
- Finance (financial capital).
- Society (social capital);
- Assets (manufactured capital); and
- Environment (natural capital).

Given considerations specific to the case of water supply in rural sub-Saharan Africa, the six themes were refined into seven sustainability factors whereby 'policy context' covers governance, strategic planning and development issues, management and human capital are combined under 'management and institutional arrangements', and manufactured capital is sub-divided into 'technology' and 'supply chains'. Therefore, the seven sustainability factors adopted for this research are:

- Policy context;
- Management and institutional arrangements;

- Financial issues;
- Community and social aspects;
- Technology;
- Environment; and
- Supply chains.

These sustainability factors formed the basis of the research framework adopted. Each factor was investigated in detail in relation to the respective research objective listed above. Consequently, this research submission consists of six refereed academic journal papers and one internationally peer reviewed conference paper, each of which addresses one of the sustainability factors.

The overall methodology of sub-dividing sustainability into 'sustainability factors' is commonly applied in sustainability studies (Luckhurst, 2003; Parry-Jones et al., 2001) and would appear to be an effective approach to investigating and analysing the issue. The limitation of this approach is that it has the potential to compartmentalise issues and make understanding of the interrelationships more difficult, however one of the aims of this critical overview is to overcome this potential constraint.

The research that led to the submitted body of work took place over approximately five years between 2001 and 2006. This involved extensive reviews of relevant literature and documentation and significant field-based data collection in Ghana, Kenya, South Africa, Uganda and Zambia. A significant proportion of the primary data collection for the research took place as part of a Knowledge and Research (KaR) project 'Guidelines for Sustainable Handpump Projects in Africa' (R7817), funded by the Department for International Development (DFID) of the British Government, and conducted by the Water, Engineering and Development Centre (WEDC), Loughborough University. As the principal researcher, the author undertook the vast majority of the research on this project. Following the completion of the KaR project in 2003 the author conducted a number of follow-up studies in Ghana and Uganda, and undertook additional research and analysis, resulting in the research publications of which this PhD submission comprises.

1.4 Research synthesis

This research synthesis starts with a discussion of the interrelationships between the sustainability factors, which is followed by a brief summary of each of the publications as it relates to the respective sustainability factor. This summary includes the research background, objectives, results and conclusions for each paper, as well as a critique of the methodology employed and general comments on the paper, including details of authorship. The interrelationships between the publications are then explored to produce an interdependent sustainability framework, which forms the basis for a programme service-based approach to rural water supply sustainability. This is followed by the overall conclusions and recommendations arising from the combined body of research.

1.4.1 Sustainability interrelationships

The Cambridge Dictionary (2007) defines sustainable as "able to continue over a period of time" or "causing little or no damage to the environment and therefore able to continue for a long time". The key to sustainability would therefore appear to be to identify what enables a water supply to continue over a long period of time. However, it is important that the sustainability of a single water point is separated from that of the project or programme under which it was installed. This research is primarily concerned about factors influencing project or programme sustainability, i.e. factors which facilitate the sustainable operation of a large number of water points, rather than micro-issues affecting the function of a particular water point. Whilst these are obviously interconnected, and lessons can be learnt from water point specific detail, it is important to focus on project and programme approaches and models that contribute to sustainability. The four success criteria linked to programme or project sustainability, as defined by WELL (1999) are effectiveness, equity, efficiency, and replicability.

Parry-Jones et al. (2000) found a wide range of definitions for sustainability relating to water supply projects, but concluded that the most frequently recurring core issues in these definitions were:

- Minimal external assistance in the long term;
- Financing of regular operation and maintenance costs by users; and
- Continued flow of benefits over a long period.

Davis and Brikké (1995) defined a drinking water supply as sustainable if:

- The water consumed is not over-exploited but naturally replenished;
- Facilities are maintained in a condition which ensures a reliable and adequate water supply; and
- The benefits of the supply continue to be realized over a prolonged period of time.

These definitions were used to develop the following definition, which is adopted for the purposes of the current research:

A water supply service is sustainable if the water sources are not over-exploited but naturally replenished, systems are maintained in a condition which ensures a reliable and adequate water supply, the benefits of the supply continue to be realised by all users indefinitely, and the service delivery process demonstrates a cost-effective use of resources that can be replicated.

A 'water service' means the ongoing provision of water of adequate quality and quantity to all people within a defined area of service. The 'users' include all those in the community that the systems serve, and the 'service delivery process' means the way in which systems are installed, operated, maintained and repaired. It is important to distinguish a 'sustainable' water service from a 'successful' one. A project or programme in which facilities are operational over a prolonged period of time due to heavy external financial and technical support may be successful, but the approach is likely to be very inefficient and impossible or difficult to replicate elsewhere. Under the definition such a project could not be said to be sustainable. The inclusion of equity as one of the criteria for sustainability is debatable, yet since water is now seen as a human right (World Water Council, 2002) it is essential that water services reach all, including the poor and vulnerable.

As described earlier, seven factors were identified as being critical to achieving rural water service sustainability. These have been used to develop a 'sustainability matrix' (see Figure 1), which shows the interrelationships between the sustainability factors.

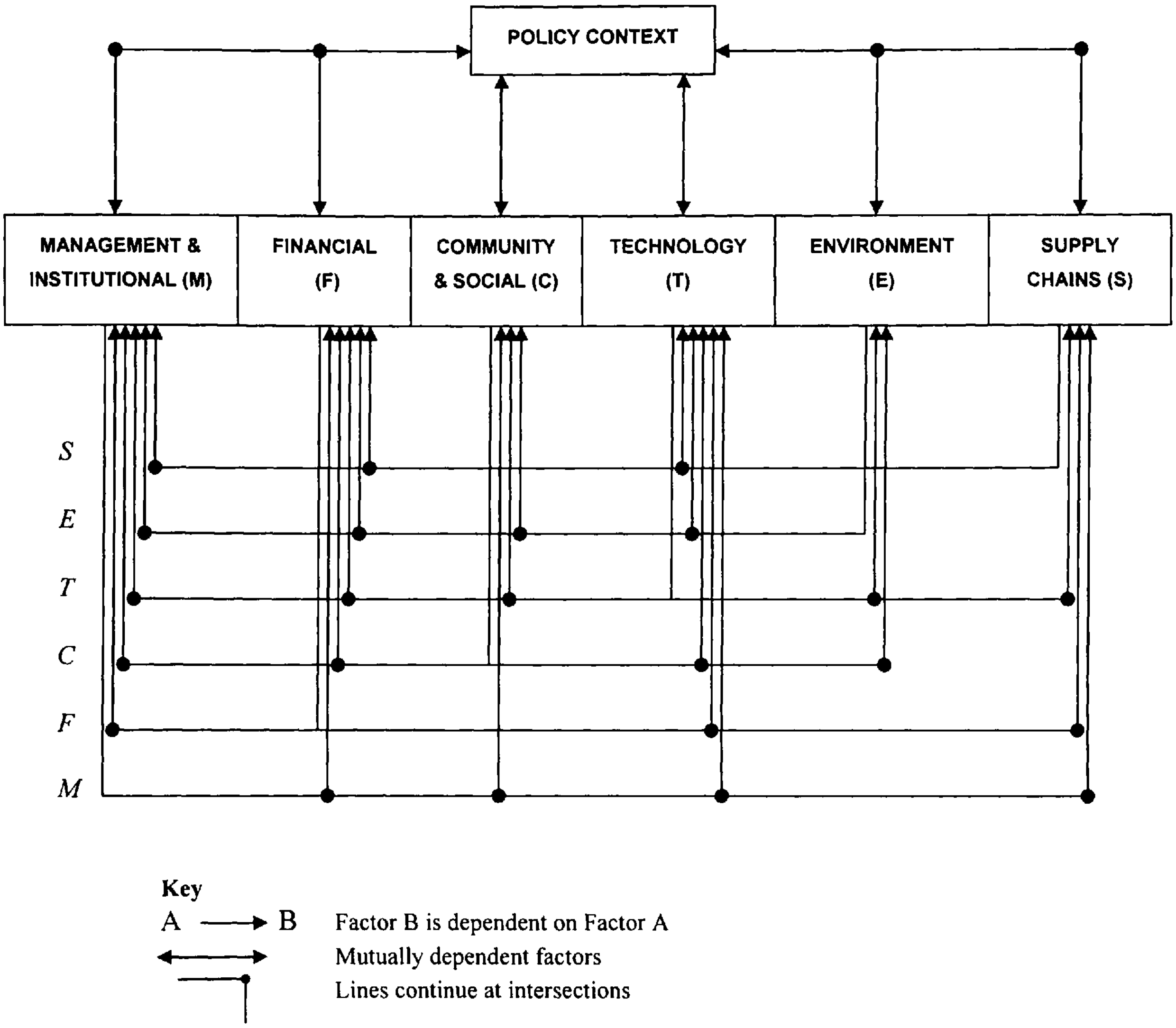


Figure 1: Sustainability matrix

As can be seen clearly from the sustainability matrix above, sustainability factors are heavily interdependent. The policy context affects all other sustainability factors and is also affected by each of them. Management and institutional arrangements affect financial issues (e.g. cost-recovery), community and social aspects (e.g. community management), technology choice (based on administrative units and capacities) and supply chains. Financial issues also affect technology choice (e.g. affordability of options), as well as management options and supply chains. Community and social aspects affect management and institutional arrangements (especially in relation to water point management), technology choice (as a result of a demand responsive approach), financial issues (especially for O&M) and the environment (with respect to land and water use in particular). Meanwhile, technology affects supply chains (equipment and tools required), financial issues (cost of construction and O&M), and the environment (dependent on the water source utilised), as well as management and community aspects, which are influenced by the type and size of system installed. The environment affects possible technology options, as well as management, financial and community aspects, particularly in relation to accessibility and potential water sources; and lastly, supply chains affect financial issues (costs of spares etc.), management issues (e.g. is Government intervention required?) and technology (i.e. components and services must be available if systems are to be kept operational).

This clearly demonstrates that no single sustainability factor can be viewed in isolation of the others. In the past, development professionals have given too much attention to single-issue solutions to sustainability. Examples of this include the focus on handpump technologies in the 1980s (Arlosoroff et al., 1987), the emphasis on community management in the late 1980s and early 1990s up until the present day (Schouten, & Moriarty, 2003), and a focus on supply chains for spare parts in recent years (Oyo, 2002).

There remains a critical need to determine how development practice can move from a cycle of sustained dependence (on external aid) to a path of supported sustainability. This relies on understanding and addressing interdependencies. It is now widely accepted that technological solutions alone will not solve the sustainability problem and that the role of the community is crucial. However, empowerment of communities is also only part of the solution. Carter et al. (1999) defines a 'sustainability chain' for community water supply consisting of motivation, maintenance, cost recovery and continuing support. This means that institutions and management arrangements have a key role to play in supporting communities. There must also be an enabling policy environment for this to be effective, and constraints caused by the physical environment, as well as threats to the environment must be considered.

1.4.2 Research publications

Each of the submitted research publications is summarised below.

1. Policy context

Harvey, P.A. "Poverty Reduction Strategies: Opportunities and threats for rural water supplies in sub-Saharan Africa". *Progress in Development Studies,* 8(1), 2008, pp. 115-128.

Poverty Reduction Strategy Papers (PRSPs) describe a country's macroeconomic, structural and social policies and programmes to promote growth and reduce poverty, as well as associated external financing needs and major sources of financing. A content analysis of PRSPs for the twenty African countries with completed papers was conducted to identify common themes which may affect water service sustainability, and to assess the relevant emphasis within PRSPs given to water and rural development. Relevant common themes were identified by searching for key recurring themes across the twenty papers and comparing these to the policy issues identified during country specific studies in Ghana, Kenya, Uganda and Zambia. These country specific studies involved content analysis of other relevant national policies and strategies, as well as key informant interviews with Government staff, private sector companies, aid agency staff and community members, to determine how policies affect the sustainability of rural water services. One limitation of this approach was that content analysis of the PRSPs was conducted primarily manually, which was time-consuming. This process could have been made more effective by using appropriate software to search through electronic files and facilitate easier comparative analysis.

This analysis of the twenty completed PRSPs across the sub-continent revealed a high degree of uniformity and three common themes in the pursuit of reduced poverty: trade liberalisation, decentralisation and privatisation; each of which poses opportunities, but also considerable threats, to the development of sustainable rural water services. Trade liberalisation will only have positive effects on service sustainability if coupled with changes in donor procurement and taxation policies. The current predominant donor procurement practices coupled with trade liberalisation actually threaten the viability of supply chains and sustainability of rural water services. Privatisation offers opportunities but policies are required to develop sufficient indigenous private sector capacity. Likewise, decentralisation processes must incorporate institutional strengthening and sustainable capacity building. An additional emerging theme was that of community management of rural water supplies, which is prescribed by many PRSPs and related national sectoral strategies yet has failed to deliver satisfactory levels of sustainability. The analysis also identified a lack of emphasis given to water supply and rural development, despite the multidimensional links between water and poverty. PRSPs are designed to promote growth and reduce poverty, yet many of their essential ingredients must be reviewed holistically if these goals are to be realised. If interdependencies between PRSP components are not recognised, and acted upon, they may reduce the sustainability of rural water services, and thus hinder rather than promote development in rural Africa.

This was an invited paper for a special issue of *Progress in Development Studies* 'General Agreement on Trade and Services (GATS) and Development: The case of the water sector'. The key findings of the paper were presented at a Symposium on the GATS and Water at Loughborough University in April 2005, which incorporated international policy initiatives relevant to the particular paper.

Progress in Development Studies
ISSN: 1464-9934

2. Management and institutional arrangements

Harvey, P.A., Uno, J. and Reed, R.A. "Management of Rural Water Services in Sub-Saharan Africa". *Proceedings of the Institute of Civil Engineers: Civil Engineering,* 159 (4), November 2006, pp. 178-184.

This sustainability factor was investigated through a combination of literature review, key informant interviews, focus group discussions and household interviews. Focus group discussions were conducted in twenty communities in Uganda, and household interviews were conducted in each community on the basis of a random sampling strategy, whereby an interview was conducted with every fifth household, reaching a total of 200 community members. Equal numbers of males and females were interviewed and took place in focus group discussions, to ensure an equal gender spread of respondents. Communities were selected on a random basis across a given geographical area. A simple survey form was developed for data collection during interviews, and a checklist was used to guide discussions to ensure consistency and comprehensive coverage. Additional survey forms were developed for key informant interviews with small and medium size enterprises, and Government and aid agency staff. Survey results were presented on the basis of percentage responses for assigned categories used in the survey forms, to facilitate ease of understanding. In addition, a project review was undertaken by contacting support agencies and consultants to identify documented cases of private sector participation in rural water service delivery. Access to key government and aid agency officials was facilitated well in the study countries, as was access to appropriate policy documents. For community surveys, much of the information from the research was qualitative data, also making analysis predominantly qualitative with limited quantitative analysis. Redesigning the survey forms to test potential correlations and facilitate greater statistical analysis would have strengthened the research approach (this also applies to the methodology for 'community and social aspects' summarised below).

The literature review revealed that private sector approaches to service delivery have been implemented in a small number of cases only, but have demonstrated considerable potential for improved sustainability, since they are built on sustainable stakeholder incentives, while community management models have in general failed to produce acceptable levels of service sustainability. There is, therefore, an apparent need for decision-makers to accept the limitations of community management and the need to explore sustainable alternatives, including increased private sector participation. Research in Uganda involving key informant interviews and focus group discussions revealed that the perceptions of government and aid agency personnel were the main barrier to indigenous private sector participation in rural water service delivery, while the resistance of communities was much less acute, with the vast majority expressing no objection in principle. Indeed, while rural community members placed importance on self-ownership of water systems and cost of services, they were far less concerned about who manages their water supply systems and did not have an inherent resistance to private sector service delivery. From these findings it is clear that private sector management models are likely to be most successful where the community retains ownership of its water supply.

This paper was discussed during a session on sustainability at the international forum of the Rural Water Supply Network in Accra, Ghana in November 2006. The research design, analysis and writing of the paper were undertaken by the first named author; J. Uno carried out most of the field data collection in Uganda; R.A. Reed provided critical review and advice.

Proceedings of the Institute of Civil Engineers: Civil Engineering
ISSN: 0965-089X
Indexed in: Science Citation Index; Current Contents; etc.
Impact Factor (2007): 0.108

3. Financial issues

Harvey, P.A. "Cost-Determination and Sustainable Financing for Rural Water Services in Sub-Saharan Africa". *Water Policy Journal,* 9 (4) 2007, pp. 373-391.

In order to determine the costs of sustainable operation and maintenance of rural water supply systems, an analysis of handpump spare parts stockists was undertaken in Ghana. The four regional outlets in the country were visited and their sales data analysed to determine the average costs of components. The estimated frequency of replacement for each different component was determined through analysis of community water committee records and respective non-governmental organisation (NGO) monitoring reports. Current costs of facilities and estimated lifespan were determined from government agency and NGO data, as were estimated costs for operation and maintenance (O&M), institutional support and rehabilitation. Costs were linked to hard currency to determine realistic and consistent average costs of components and services. Subsequently a realistic cost-determination model was developed and demonstrated. There was, however, the need for a certain degree of extrapolation in estimating the frequency of replacement for components and estimated lifespan of systems due to a limited range of data. Financial forecasting and modelling were based on the use of an Annuity Factor (a function of the expected life-span of the equipment in years and the interest rate) to allow for devaluation, which overrides inflation effects in many low-income countries. Community financing strategies were explored on the basis of community interviews and focus group discussions in Ghana, Kenya, Uganda and Zambia (see 'community and social aspects' for more details), as well as additional review of available literature.

The paper argues that access to safe, sufficient and affordable water in rural Africa will not increase unless practicable long-term financing strategies are developed which ensure the sustainability of existing water services, and that in order to do this, international donors and national governments must confront the true costs associated with sustained service provision. The cost-determination methodology developed can be applied to develop a tariff hierarchy for rural water services for different levels of cost-recovery and to determine the true costs of service provision to users and/or support agencies. This can be used as a planning tool for implementing agencies. The investigation into community financing strategies concludes that these must be matched to specific communities and their economic characteristics; a blanket approach is unlikely to function effectively. Innovative strategies are also needed to ensure that the rural poor are adequately served, for which a realistic, targeted and transparent approach to subsidy is required.

Water Policy
ISSN: 1366-7017
Official Journal of the World Water Council
Recently accepted for inclusion in Science Citation Index Expanded and Current Contents/Agriculture, Biology and Environmental Sciences (no impact factor available).

4. Community and social aspects

Harvey, P.A. and Reed, R.A. "Community-Managed Water Supplies in Africa: Sustainable or dispensable?". *Community Development Journal,* 42 (3) 2007, pp. 365-378.

This sustainability factor was investigated primarily by household interviews and community focus group discussions in Ghana, Kenya, Uganda and Zambia. An average of approximately 60 communities was visited in each country resulting in a total sample size of 243 communities. Focus group discussions were conducted in each community, and household interviews were conducted on the basis of a random sampling strategy, whereby an interview was conducted with every fifth household. Equal numbers of males and females were interviewed and took place in focus group discussions, to ensure an equal gender spread of respondents. Communities were selected on a random basis across at least two regions or provinces in each country. The survey forms and checklists used to guide interviews and discussions facilitated comprehensive data collection. These were applied in a flexible way and revised during field surveys to improve and adapt to local conditions; consequently, slightly different survey tools were used in different countries due to variations in implementation and management models which made cross-country data analysis complex. However, the community and household sampling worked effectively, and household interviews and focus group discussions were generally successful in gathering the required data. A high response rate was achieved through face-to-face interviews, and surveys were conducted relatively quickly at relatively low cost. As a result, on the basis of the community surveys the most common reasons for water supply system failure were identified. The relationship between ownership and operational failure rate was also investigated, as was that between institutional support and operational failure rate. Alternative strategies to community management were also explored based on community responses and existing documentation.

This survey identified the most prevalent reasons for the failure of rural water systems, all of which were related to community management. Consequently, the paper explores the need to distinguish between 'community participation' which is a prerequisite for water service sustainability, and 'community management', which is not. The survey findings also indicated that many assumptions relating to community management applied in project implementation are incorrect. For example, community ownership does not automatically lead to a strong sense of responsibility for operation and maintenance. Community heterogeneity and individual rights and preferences must be recognised, as must socio-cultural variations. If community management systems are to be sustainable they require ongoing support from an overseeing institution to provide encouragement and motivation, monitoring, participatory planning, capacity building and specialist technical assistance. If such support is not available, alternatives such as household water supplies and private sector service delivery should be considered.

The research was conducted and the paper written by first named author; R.A. Reed provided critical review and advice.

Community Development Journal
ISSN 0010-3802

5. Technology

Harvey, P.A. and Drouin, T. "The Case for the Rope-Pump in Africa: A comparative performance analysis". *Journal of Water and Health,* 4 (4), 2006, pp. 499-510.

The conventional handpump is the most popular technology choice for improved potable water supplies in rural sub-Saharan Africa. To date, however, it has failed to deliver satisfactory levels of sustainability, largely due to inadequate maintenance capacity. An alternative option to standardised imported handpumps is the locally manufactured rope-pump, which is considerably cheaper and easier to maintain but has been rejected in the past due to fears of impaired water quality. This paper presents the key aspects of a study in northern Ghana, which compared the performance of rope-pumps with that of conventional handpumps, to determine whether or not the rope-pump provides a viable alternative for community water supplies across the sub-continent. The project area was selected on the basis that rope-pumps and conventional handpumps were installed on the same type of water sources in near-identical conditions. Focus group discussions were conducted in each community following a uniform approach, and a sanitary inspection was conducted for each well site in the study using a standard sanitary inspection form. Microbiological water quality at each water point was analysed for presumptive counts of thermotolerant coliforms, using the membrane filtration technique. The probability plot correlation coefficient test and Wilcoxon's rank-sum test were then applied to this data to compare the microbiological water quality data obtained for each pump type. The quality of the microbiological water quality data was questionable since the presumptive counts of thermotolerant coliforms seemed excessively high for some water samples. This may have been due to problems with the membrane filtration equipment or user error. However, the consistency between results across all water point types indicates consistent practice and reinforces the validity of the results on a comparative basis. In order to determine the initial and ongoing costs, interviews were conducted with communities, private sector suppliers and sector professionals; sales data from suppliers and from previous studies were also used to back-up the findings. Simple technical assessments were conducted for each pump visited and were backed up with available technical data from manufacturers and impartial assessors. A Comparative Performance Analysis (CPA) method was developed to compare the performance of the two pumps on the basis of the following variable factors: capital costs; impact on microbiological water quality; maintenance costs; maximum pumping head; flow rate; and impact on turbidity. NGOs and communities were asked to rank the range of variables in terms of their relative importance, and on the basis of the average results of this ranking exercise, the importance of each different factor was then weighted and applied in the CPA method.

The findings of the study indicated that the rope-pump out-performed the conventional handpump as a community water technology option for hand-dug wells in all key areas, including technical performance, ease of operation and maintenance, and cost; and that contrary to widespread perceptions there was no significant difference between pump types with respect to the impact on microbiological water quality. Consequently, the rope-pump provides a significant technological opportunity to improve water supply sustainability in Africa. The CPA methodology developed can be applied in future studies to evaluate effectively different water technologies in relation to their overall performance, cost and sustainability.

This paper was disseminated to agencies working in rural water supply, including WaterAid and UNICEF, and has contributed to the recent increased uptake of rope-pumps in sub-Saharan African countries, including Ghana, Kenya, Uganda and Zambia. The research design, analysis and writing of the paper were undertaken by the first named author; the field data collection in Ghana was carried out by T. Drouin.

Journal of Water and Health
ISSN: 1477-8920
Published by IWA Publishing in collaboration with the World Health Organization (WHO), *Journal of Water and Health* is the highest profile journal dealing specifically with water and health in low-income countries.
Indexed in: Science Citation Index Expanded and Current Contents/Agriculture, Biology and Environmental Sciences.
Impact Factor (2007): 1.164

6. Environment

Harvey, P.A. "Borehole Sustainability in Rural Africa: An analysis of routine field data". *Proceedings of 30th WEDC Conference,* Loughborough University, 2004, pp. 339-346.

This paper examines the key environmental issue that affects the sustainability of water supplies in much of rural sub-Saharan Africa, namely the rapid drying-up of drilled boreholes. Given the heavy reliance on groundwater sources accessed by handpump-equipped boreholes, the study attempts to identify reasons for rapid-onset borehole failure, using Ghana as a case study. Data routinely collected during borehole drilling and development were analysed with respect to rapid-onset failure rates of boreholes. It was deemed important to investigate readily available field data rather than detailed scientific data, since many drillers in rural Africa lack the hydrogeological expertise and specialist equipment required to gather the latter. A survey of 492 handpump-equipped boreholes in Ghana was conducted to determine the rate of failure of water points due to both pump failure and borehole failure. In order to determine the possible causes of borehole failure, the following variables were analysed for each borehole: initial recorded yield of borehole; borehole depth in relation to dynamic water level; depth of cylinder below dynamic water level; and season during which drilling took place. Due to incomplete construction and assessment data for some boreholes, the total sample size was reduced to 302. In addition to the above variables, the borehole failure rate in each district was compared to the respective borehole siting success rate, and the relationship between borehole age and failure rate was also investigated. Graphical comparative analysis of borehole data variables was applied by separating failed and non-failed boreholes. Numerical analysis was then applied to variables of interest, and graphical analysis of borehole failure rate and monthly rainfall was used. Statistical analysis using correlation coefficients was applied to assess the relationship between borehole failure rate and time of drilling, and between borehole failure rate and borehole siting success rate. This approach was successful in identifying data patterns and relationships, and the statistical analysis produced significant results. The main limitation of the research was the limited hydrogeological data available for the project area, which meant that it was difficult to assess the aquifer recharge potential in different areas.

The study revealed that the initial measured yield of a borehole was the single largest factor that influenced subsequent borehole failure. It also showed that the likelihood of borehole failure increased by a factor of six when drilling occurred during the wet season, and discovered a strong correlation between monthly precipitation and respective failure rates for boreholes drilled in each month. On the basis of these results, a number of practical recommendations are made for rural borehole drillers and project managers. In particular, it was identified that seasonal compensation drilling strategies are required, even for handpump-equipped boreholes.

This paper was presented at the 30th WEDC Conference ‘People-Centred Solutions to Water and Environmental Sanitation’ in Vientiane, Laos in November 2004, and the key recommendations were disseminated to agencies working in rural water supply via the West Africa Water Initiative.

Proceedings of the 30th WEDC Conference
ISBN: 978-1-84380-087-3

7. Supply chains

Harvey, P.A. and Reed, R.A. "Sustainable Supply Chains for Rural Water Supplies in Africa". *Proceedings of the Institution of Civil Engineers: Engineering Sustainability*, 159(1), March 2006, pp. 31-39.

This paper examines the issue of spare parts supply for pump maintenance, which is often cited as one of the weak links in the quest for sustainability, since there are very few examples of sustainable supply chains throughout the sub-continent. The sustainability factor was investigated by identifying the challenges for spare parts supply chains and barriers to sustainability from a literature review and synthesis of key informant interviews, and community interviews and discussions, in Ghana, Kenya, Uganda and Zambia. A number of key barriers to sustainability were identified which are specific to the rural African context. These include the separation of the supply of pumps from the supply of associated spares, low pump density resulting in low profits, poverty and immobility among end-users, inflexible approaches to technology choice, and restrictive policies and maintenance systems. The issue of supply chain viability was then investigated further by testing the commercial viability of spare parts supply at the user level, by means of a System Density Breakpoint (SDB).

The SDB was devised to establish the density of systems required to produce enough demand to generate sufficient turnover of spares and sufficient profit for the retailer. This was successfully applied using data from Ghana to demonstrate the process. These data included minimum annual profit required by the retailer for commercial viability, the average profit per spare part weighted for frequency of replacement need, the average time period between each spare part required for any given pump, and the radius of access (which is defined as the average of the maximum distances from the retailer to potential customers). To apply the SDB determination process these data were obtained via interviews with retailers, an analysis of spare parts retailer records, and NGO monitoring reports. Retail data were analysed and linked to hard currency to determine realistic and consistent average costs of components, while consumption rates were estimated by extrapolating available monitoring data.

The findings indicated that the supply of handpump spare parts to rural areas is not a viable stand-alone commercial activity, despite many initiatives with this ultimate aim, primarily due to insufficient system density. The paper identifies a critical need for realism in the rural water sector and for implementers to move away from the perceived wisdom that the private sector alone is the solution to the spare parts conundrum; it also outlines a number of sustainable solutions to the problem. Integrated service provision, appropriate technology choice and, where necessary, non-profit sector options provide a multifaceted solution that must be embraced if present and future rural water services are to be sustained. The System Density Breakpoint (SDP) model developed can also be applied as a planning tool to test the viability of supply chains for rural water supply systems in other areas.

This paper was shortlisted by the editorial panel of *Engineering Sustainability* for a best paper award in 2006. The research was conducted and the paper written by first named author; R.A. Reed provided critical review and advice.

Proceedings of the Institution of Civil Engineers: Engineering Sustainability
ISSN: 1478-4629

1.4.3 Interrelationships between publications

As indicated above, there are numerous links between the different sustainability factors. To assess these links in greater detail the interrelationships between the key aspects of the submitted research publications are outlined. Sustainability factors are indicated in **bold** and additional recurring themes are <u>underlined</u>.

1. Policy context

Harvey, P.A. "Poverty Reduction Strategies: Opportunities and threats for rural water supplies in sub-Saharan Africa". *Progress in Development Studies,* 8(1), 2008, pp. 115-128.

Four key themes emerge from this paper, which pose opportunities, but also considerable threats, to the development of sustainable rural water services:

a) Trade liberalisation will only have positive effects on service sustainability if coupled with changes in donor procurement and taxation policies, which affect **technology** and **supply chains**.

b) Decentralisation processes must incorporate **institutional** strengthening and sustainable capacity building.

c) Privatisation offers opportunities but an enabling **policy** environment is required to develop sufficient indigenous private sector capacity.

d) **Community** management of rural water supplies, is prescribed by many PRSPs and related national sectoral strategies, yet has failed to deliver satisfactory levels of sustainability.

2. Management and institutional arrangements

Harvey, P.A., Uno, J. and Reed, R.A. "Management of Rural Water Services in Sub-Saharan Africa". *Proceedings of the Institute of Civil Engineers: Civil Engineering,* 159 (4), November 2006, pp. 178-184.

The key findings and recommendations from this paper are as follows:

a) There is a need for donors and decision-makers to accept the limitations of **community** management and the need to explore sustainable alternatives, including increased private sector participation.

b) User **communities** do not have an inherent resistance to private sector management of services, but they do place importance on self-ownership of their water systems and **financial** cost of services is a key determinant in their choice of model.

c) Private sector management of rural water services in sub-Saharan Africa remains uncommon, but where it has been applied it has been relatively successful since it is built on sustainable stakeholder incentives.

d) The negative perceptions of government **institutions** and aid agency personnel are one of the principal barriers to indigenous private sector participation in rural water service delivery.

e) The indigenous private sector in many parts of rural Africa currently has limited capacity and support from decentralised government **institutions** may be required initially to build capacity, stimulate participation and develop local markets

3. Financial issues

Harvey, P.A. "Cost-Determination and Sustainable Financing for Rural Water Services in Sub-Saharan Africa". *Water Policy Journal,* 9 (4) 2007, pp. 373-391.

The key findings and recommendations from this paper are as follows:

a) Practicable long-term **financing** strategies need to be developed which ensure the sustainability of existing water services.

b) International donors and national governments must confront the true costs associated with sustained service provision.

c) The overall **financial** cost of service delivery must be based on respective cost estimates for operation and maintenance, **institutional** support, and rehabilitation and expansion. This can then be used to develop a tariff hierarchy for different levels of cost-recovery.

d) **Community financing** mechanisms must be matched to specific **communities** and their economic characteristics. Innovative strategies are also needed to ensure that the rural poor are adequately served, for which an appropriate **institutional** and **policy** framework is required.

4. Community and social aspects

Harvey, P.A. and Reed, R.A. "Community-Managed Water Supplies in Africa: Sustainable or dispensable?". *Community Development Journal,* 42 (3) 2007, pp. 365-378.

The key findings and recommendations from this paper are as follows:

a) '**Community** participation' is a prerequisite for water service sustainability, but '**community management**' is not. Government **policies** should not limit rural water service sustainability by prescribing **community management** as the only management option.

b) The most prevalent reasons for the failure of rural water systems are related to **community management**.

c) **Community** heterogeneity and individual rights and preferences must be recognised, as must socio-cultural variations.

d) If **community management** systems are to be sustainable they require ongoing support from an overseeing **institution** to provide encouragement and motivation, monitoring, participatory planning, capacity building and specialist **technical** assistance.

e) If **institutional** support is not available, alternatives such as household water supplies and private sector service delivery should be considered.

5. Technology

Harvey, P.A. and Drouin, T. "The Case for the Rope-Pump in Africa: A comparative performance analysis". *Journal of Water and Health,* 4 (4), 2006, pp. 499-510.

The key findings and recommendations from this paper are as follows:

a) The rope-pump demonstrates increased **technical** performance for all of the assessment parameters in comparison to a conventional low-lift handpump, and has a near identical impact on microbiological water quality despite contrary negative perceptions.

b) The rope-pump is significantly cheaper **financially** in terms of both capital costs and maintenance costs.

c) The **financial** and **technical** advantages can be coupled with the fact that the rope-pumps are manufactured locally, helping to develop indigenous <u>private sector capacity</u>.

d) In terms of **financial** viability and **technical** reliability, benefits for the **communities**, and sustainability, it can be argued that the rope-pump should be actively promoted as a low-lift pump for community water supplies.

6. Environment

Harvey, P.A. "Borehole Sustainability in Rural Africa: An analysis of routine field data". *Proceedings of 30th WEDC Conference,* Loughborough University, 2004, pp. 339-346.

The key findings and recommendations from this paper are as follows:

a) The initial measured yield of a borehole is the single largest factor that influences subsequent borehole failure. It is important that realistic minimum guideline figures are set out in government **policy**, to minimise waste of **financial** resources.

b) The required yield should be matched to forecasted water demand for each specific borehole, based on the **community** needs and water usage.

c) Guidelines for seasonal compensation drilling strategies should be developed by Government **institutions,** and <u>private sector</u> drilling <u>capacity</u> developed accordingly.

d) Government **institutions** should facilitate monitoring of boreholes and regulate private sector drilling operations.

e) Private sector professionals involved in groundwater development must have the skills, knowledge and capacity required to be effective, so that they can acquire a real understanding of the **environment** in which they operate.

7. Supply chains

Harvey, P.A. and Reed, R.A. "Sustainable Supply Chains for Rural Water Supplies in Africa". *Proceedings of the Institution of Civil Engineers: Engineering Sustainability*, 159(1), March 2006, pp. 31-39.

The key findings and recommendations from this paper are as follows:

a) It is clear that the private sector business approach to spare parts supply is not viable unless integrated with the provision of pumps and/or **technical** services. This requires a paradigm shift away from externally-driven donor-led projects to local rural services that develop local capacities and promote local economic growth.

b) A parallel shift from **community management** to public **private** management and maintenance also provides significant opportunities for sustainable economic growth and sustainable water provision.

c) **Technology** choice has a key role to play, and simple, local options may considerably reduce the problems created by imported technologies, especially where donors import goods tax-free.

d) In some situations, particularly where **communities** are sparsely distributed and access is difficult, it must be accepted that non-profit or subsidised approaches are likely to be the only viable supply chain option.

e) There is an acute need for realism among donors, Governments, **policy**-makers and implementers if supply chains are to be sustainable and if the benefits of potable water in poor rural communities are to be realised on a long-term basis throughout sub-Saharan Africa.

1.4.4 Interdependent sustainability framework

As can be seen from the above summaries there are many links between the different sustainability factors and many common themes that emerge from the published papers. These common themes can be summarised as follows:

- Private sector participation provides a key opportunity to establish a chain of sustainable incentives;
- Capacity building for private sector and government institutions is essential;
- Decentralisation provides opportunities for institutional support for community management and regulation but requires significant capacity;
- Donors and donor practices have key roles to play in promoting sustainability;
- Monitoring of water services, water sources, and community management and financing is essential if services are to be sustained.

Based on the submitted body of work a number of interrelated sustainability qualifiers can be developed, which can be applied in determining whether rural water services will be sustainable. The corresponding qualifiers for each sustainability factor are summarised in Table 1. These also represent appropriate planning and management objectives.

Table 1: Sustainability qualifiers

SUSTAINABILITY FACTOR	SUSTAINABILITY QUALIFIERS
Policy context	• Policy does not dictate management arrangements • Capacity is sufficient to implement relevant policies • Donor practices promote local procurement and/or production • Government attitudes and practices do not hinder indigenous private sector participation
Management and institutional arrangements	• Institutional support for community management is provided • Private sector alternatives to community management are investigated and promoted • Local Government capacity is sufficient to fulfil regulatory and monitoring roles
Financial issues	• External support is minimised and strategies target self supply • Sustainable subsidies are developed to serve the poorest and most vulnerable • Transparency and accountability measures are in place for financial management bodies (Government and non-governmental) • Realistic cost-recovery targets are clearly defined and water tariffs set accordingly • Sustainable community financing strategies are developed
Community and social aspects	• Communities are presented with a range of management models to choose from • Demand is stimulated based on a wide range of community needs (i.e. not just health) • Community cohesion is not assumed and heterogeneity is recognised as appropriate • Differing levels of poverty are recognised and targeted subsidies developed where needed
Technology	• Appropriate technology choice is promoted, especially that which is closest to the user (e.g. locally produced rope-pumps) • Flexibility in technology options is available and communities have a real choice • There is limited or no importation of specialist equipment • Private sector capacity is developed for drilling and development
Environment	• Groundwater monitoring systems are in place for water quality and quantity • Local Government regulation and monitoring of private sector operators and water resources occurs
Supply chains	• Supply chains for spare parts are linked with manufacturing, technical services and/or pump sales • Indigenous private sector development is promoted with realistic incentives • Non-profit sector support is utilised where no other options are commercially viable

1.4.5 A programme service-based approach to rural water sustainability

Given the combined findings from all of the sustainability factors, and the sustainability indicators outlined above, it is clear that there is need for a paradigm shift from the traditional project facility-based approach of the past. In order to ensure that a holistic approach to sustainability is adopted there is a need to move towards a programme service-based approach. Table 2 compares the project approach and the programme approach in relation to each of the sustainability factors.

Focusing on 'programmes' rather than 'projects', and 'services' rather than 'facilities', presents an excellent opportunity to enhance the sustainability of water provision to rural communities in low-income countries. The programme approach is built on partnerships between central government, international donors, regional and local government, NGOs, community based organisations (CBOs) and ultimately, individual members of rural communities. Since most sub-Saharan African countries have adopted decentralisation policies (Olowu, 1994) local Government institutions have the primary responsibility for service delivery. However, such an approach will be successful only if local government institutions acquire sufficient capacity and resources to be able to deliver, and if corruption at all levels can be minimised.

The most fundamental way in which a programme differs from a project is that it has an indefinite timeframe and consequently there are no arbitrary time limits that drive the planning and implementation process. A programme is built on permanent partnerships and consequently there is no requirement for 'exit-strategies' or 'handovers'. This is crucially important in terms of sustainable water provision since it is now increasingly accepted that community-managed water supplies require ongoing support from an appropriate institution (Carter et al., 1999). Water supply is a service, just as healthcare is a service, and any service requires ongoing management. The focus on the facility or static infrastructure (which it is hoped that the users will keep going somehow) detracts from the importance of managing and maintaining a water service, which is a dynamic process. The delivery of a service also implies a longer-term view, which recognises the fundamental human right of access to safe water. This means that governments should not abrogate all responsibility for service provision to the rural poor, but should play a key role in service delivery through appropriate support, including effective regulation.

Table 2: Advantages of programme service-based approach over project facility-based approach

Sustainability factor	*Project*	*Programme*
Policy context	The influence on policy is minimized by the time-frame of the project	There is potential to develop advocacy strategies to influence long-term policy and strategy change
Management and institutional arrangements	Projects are often donor-driven and implemented by NGOs / consultants who leave the area after a finite period	Local government and sustainable institutions in partnership with the private sector take the key roles
Community and social aspects	The need for a project 'handover' transfers all O&M responsibility to users with little or no external support	Sustainable partnerships can be developed over time and ongoing institutional support provided to communities Communities are given choice to be or not be service-provider
Financial issues	Time-bound budgetary requirements limit sustainable financing mechanisms Users pay for maintenance and upkeep of a single facility only	Budgetary allocations can be made for institutional support for communities and long-term incremental strategies Users pay for water service which includes the cost of asset replacement for which subsidy may be available
Technology	Technology choice often remains rigid with a finite lifespan and there is no time to investigate longer-term solutions	Allocations for research and development can investigate alternative technologies A flexible approach to technology is adopted allowing it be upgraded over time and respond to environmental changes
Environment	Initial environmental assessments may be conducted during construction but there is no follow-up	Long-term strategies can be put in place to monitor water resources and environmental issues
Supply chains	The need for an exit strategy has led to the idea of a 'seed fund' for private spare parts supply – this has not worked Maintenance and repair focused on the specific facilities	Incremental strategies can be developed to encourage spares supply by linking with other programme activities Maintenance and repair are inherent components of water service

The service approach means that users pay for water rather than for O&M of a single facility. By paying for a water service they are paying for the delivery of water on a sustainable basis. This service must, therefore, include monitoring and regulation to ensure that safe and adequate water is provided at affordable cost, and should also include the cost of asset replacement. As part of a programme service-based approach the potential need for subsidy for such activities must be recognised, especially for poorer communities and households. Consequently, appropriate subsidy strategies need to be developed, whether using public funds, private funds, or cross-subsidies.

By focusing on a water service, the emphasis is on the provision of safe drinking water. This facilitates wider technology choice and promotes the upgradability of systems to improve service levels, rather than accepting that water has been provided and that's the end of the matter, as is the case in the facility-based project approach. Flexible technology, which can be upgraded over time, can respond to the needs and demands of the community, as well as to environmental changes such as depletion of water resources, which should be monitored as part of the service provided. Where possible, communities should be given the choice of whether to be service-provider supported by a (Government) regulator, or whether they would prefer a private sector service-provider.

Perhaps the most important advantage is that the delivery of a water service is an indefinite process, and consequently, a path of supported sustainability involving all key stakeholders must be developed and followed. Figure 2 outlines the key components needed to develop a rural water supply programme and service-based approach, namely, building partnerships, developing the programme, identifying (long-term) stakeholder roles and defining the water service. All of which is assessed through regular programme reviews.

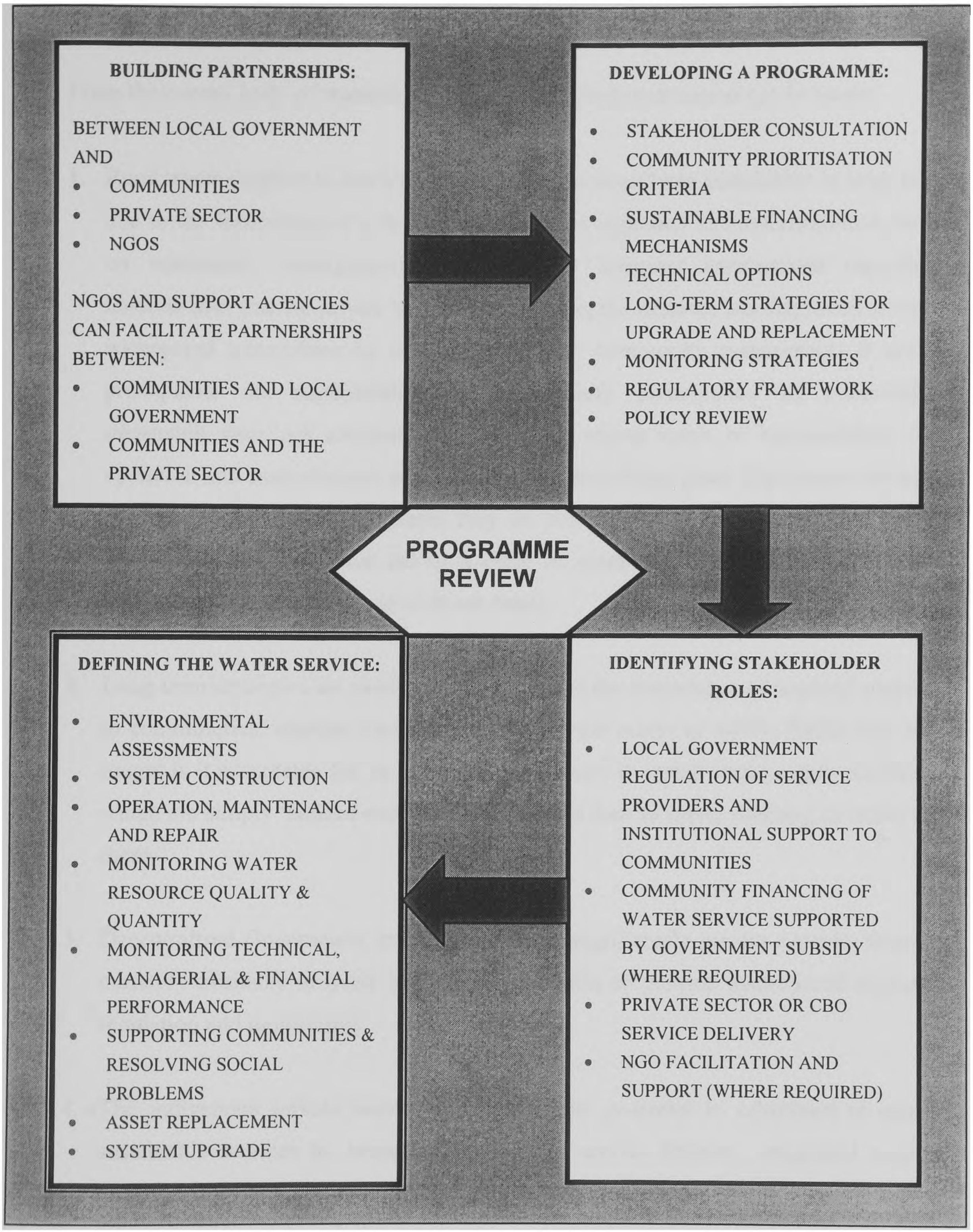


Figure 2. Service-based programme approach to rural water supply

1.5 Conclusions

From the overall body of research the following general conclusions can be made:

1. Rural water supplies in low-income countries have not been sustainable in large part due to the limitations of a facility-based project approach to implementation, built on community management and based on incorrect assumptions regarding communities and the private sector. For example, the research has disproved several widespread perceptions by demonstrating that: community management is not a prerequisite for sustainability, but community participation is; community ownership does not automatically lead to a strong sense of responsibility for operation and maintenance; and while user communities place importance on self-ownership of their water systems they do not necessarily want to manage them. Such misconceptions have led to a cycle of sustained dependency based on an ineffective and inefficient use of donor funds.

2. Long-term strategies are needed which recognise the importance of ongoing support to communities, whether Government, the private sector or NGOs fulfill this. No longer is it acceptable for an implementing agency to install water supply facilities which are simply 'handed over' to the users, and then to leave, washing its hands of them.

3. Decentralised Government institutions require significantly greater capacity than is currently available in many low-income countries to provide institutional support, regulation and monitoring.

4. The indigenous private sector has considerable potential to contribute to more sustainable services by becoming involved in service delivery, integrated supply chains, and local appropriate technology manufacture. Communities do not have an inherent resistance to private sector management of services but current Government and donor attitudes and practices limit sustainable incentives for private sector participation.

5. Donor-influenced policies and strategies in the areas of cost-recovery, community management, private sector involvement, technology choice, procurement and supply chains must be revised to impact positively on sustainability levels.

6. There is a need to adopt a holistic approach, which considers the different sustainability factors and their interrelationships, in order to tackle the issue of rural water service sustainability. This can be achieved by adopting a service-based programme approach to implementation.

7. Rural water supply programmes need to be developed which recognise that increasing sustainable access to potable water is an ongoing process that cannot be rushed. A path of supported sustainability through a programmatic approach is required. Potential advantages of the programme approach include: sustained management, financing and regulation; appropriate policy-change, technology choice and maintenance solutions; and long-term asset-replacement strategies.

8. Whether through central budget support or regional programmes it is important that donors, governments and implementers subscribe to the concept of *rural water services*. This does not mean that these services cannot be financed predominantly by the end-users but does recognise the importance of institutional management, support to communities, monitoring and regulation, and reaffirms the role of governments in ensuring that fundamental human rights are met.

9. A paradigm shift is required in rural water provision in low-income countries, from projects to programmes and from facilities to services. Such a transition is long overdue, and without it the rural poor will continue to suffer the effects of poor access and unsafe drinking water, simply because improvements in water supply are not sustained.

1.6 Recommendations

In addition to the general conclusions listed above there are also some specific recommendations that arise from the research:

- It is recommended that future research be undertaken to determine specific reasons as to why community management structures break down and identify the key determinants as to why community management works in some communities but not in others.

- More pilot projects should be implemented involving private sector service delivery in rural water supply, especially in relation to O&M and integrated supply chains. These should be accompanied by rigorous monitoring and action research to determine the effectiveness of private sector participation in different environments.

- Further research is required to investigate different community financing strategies and to determine the costs of service provision in different settings. This will help Governments and donors to calculate long-term financial requirements and determine budgetary allocations.

- Additional research is also required to assess different technologies and water resource development strategies (e.g. drilling) in relation to sustainability.

- In programme planning and monitoring the following tools developed during the course of the research can be applied to a specific geographical area:
    - The cost-determination methodology can be applied to develop a tariff hierarchy for rural water services and to determine the true costs of service provision to users and/or support agencies.
    - The Comparative Performance Analysis (CPA) methodology can be applied to evaluate different water technologies in relation to their overall performance, cost and sustainability.
    - The System Density Breakpoint (SDP) model can be applied to test the viability of supply chains for rural water supply systems.

- The key findings from this research should be incorporated into advocacy strategies to improve the sustainability of rural water services in low-income countries. In particular, the interdependencies between different sustainability factors need to be better understood by policy-makers and implementers.

- Some of the publications included in this submission have been disseminated to national Governments and implementing agencies via the Rural Water Supply Network (RWSN). It is recommended that this process be improved by incorporating the key findings into appropriate advocacy tools to make them more accessible to a variety of stakeholders. These should be targeted at relevant decision-makers and incorporate specific interdependent issues such as:
    - Procurement practices, private sector participation and supply chains;
    - Institutional support, budgeting, monitoring and regulation;
    - Community participation, community management and sustainable financing;
    - Technology choice, operation and maintenance, and environmental sustainability.

Publications

1. Policy context

Harvey, P.A. "Poverty Reduction Strategies: Opportunities and threats for rural water supplies in sub-Saharan Africa". *Progress in Development Studies,* 8(1), 2008, pp. 115-128.

2. Management and institutional arrangements

Harvey, P.A., Uno, J. and Reed, R.A. "Management of Rural Water Services in Sub-Saharan Africa". *Proceedings of the Institute of Civil Engineers: Civil Engineering,* 159 (4), November 2006, pp. 178-184.

3. Financial issues

Harvey, P.A. "Cost-Determination and Sustainable Financing for Rural Water Services in Sub-Saharan Africa". *Water Policy Journal,* 9 (4), 2007, pp. 373-391.

4. Community and social aspects

Harvey, P.A. and Reed, R.A. "Community-Managed Water Supplies in Africa: Sustainable or dispensable?". *Community Development Journal,* 42 (3), 2007, pp. 365-378.

5. Technology

Harvey, P.A. and Drouin, T. "The Case for the Rope-Pump in Africa: A comparative performance analysis". *Journal of Water and Health,* 4 (4), 2006, pp. 499-510.

6. Environment

Harvey, P.A. "Borehole Sustainability in Rural Africa: An analysis of routine field data". *Proceedings of 30th WEDC Conference,* Loughborough University, 2004, pp. 339-346.

7. Supply chains

Harvey, P.A. and Reed, R.A. "Sustainable Supply Chains for Rural Water Supplies in Africa". *Proceedings of the Institution of Civil Engineers: Engineering Sustainability,* 159(1), March 2006, pp. 31-39.

1. POLICY CONTEXT

Progress in Development Studies 8, 1 (2008) pp. 115–128

Poverty Reduction Strategies: opportunities and threats for sustainable rural water services in sub-Saharan Africa

Peter Harvey

Water, Engineering and Development Centre,
Loughborough University, LE11 3TU, UK

Abstract: The links between access to safe water and poverty alleviation are multifaceted, but can be realized only if water supplies are sustained. Poverty Reduction Strategy Papers (PRSPs) have been developed by many low-income countries in conjunction with the World Bank and International Monetary Fund, and describe each country's macroeconomic, structural and social policies and programmes to promote growth and reduce poverty. An analysis of PRSPs in sub-Saharan Africa revealed insufficient attention to water and rural development and identified three common themes in the pursuit of reduced poverty: trade liberalization, decentralization and privatization; each of which poses opportunities, but also considerable threats, to the development of sustainable rural water services. An additional theme is that of community management of water services, which is prescribed by many PRSPs and related national sectoral strategies, yet has failed to deliver satisfactory levels of sustainability. PRSPs are designed to promote growth and reduce poverty, yet many of their essential ingredients threaten to reduce the sustainability of rural water services and thus hinder rather than promote development and poverty alleviation in rural Africa.

Key words: Africa, PRSPs, poverty, rural, water, sustainability.

I Introduction

This paper aims to contribute to the policy debate around the relationship between water supply and poverty, and to evaluate the potential effects of national Poverty Reduction Strategy Papers (PRSPs) and related policies on rural water service sustainability in sub-Saharan Africa.

When poor people are directly asked about poverty, in the majority of cases they identify the lack of access to water as one of the key causes of poverty and improving access to water as one of the top priorities in reducing poverty (Calaguas and O'Connell, 2003). The links between water and poverty are multifaceted, and sustainable access to safe water

10.1177/146499340700800110

supplies can go a long way to ameliorate the effects of poverty. Figure 1 summarizes the key positive impacts of safe water provision on poverty. These are largely interdependent, and include:

- direct health benefits through decreased morbidity and mortality;
- higher productivity due to improved health;
- subsequent reduced spending on medicines and healthcare;
- more time available for water-fetchers for productive use;
- increased school attendance, especially among girls, as a result of reduced time used in fetching water; and
- increased potential for water use for income generating activities.

Traditionally, the water sector has disseminated the importance of improved water supply primarily in relation to public health (Esrey and Habicht, 1986; UNICEF/WHO, 2000), but there is now increased awareness among sector professionals of the links between water and poverty. The extent and significance of water-related poverty was recognized at the International Freshwater Conference held in Bonn in 2001, which reiterated the importance of achieving safe, affordable and sustainable water access for poor populations, as a central global concern of poverty reduction (ODI, 2002). It is also now generally accepted that poverty transcends pure economic disadvantage, but impacts on general well-being and health, as well as social, educational and economic opportunity. Water is defined by the Humanitarian Charter as a basic human right; consequently, providing sustainable access to safe water through appropriate services has the potential to promote justice and dignity, and to empower the poor.

The fact that 53 percent of people in rural sub-Saharan Africa lacked access to safe water in 2000 as opposed to only 17 percent of their urban counterparts (UNICEF/WHO, 2000), illustrates the necessary emphasis that should

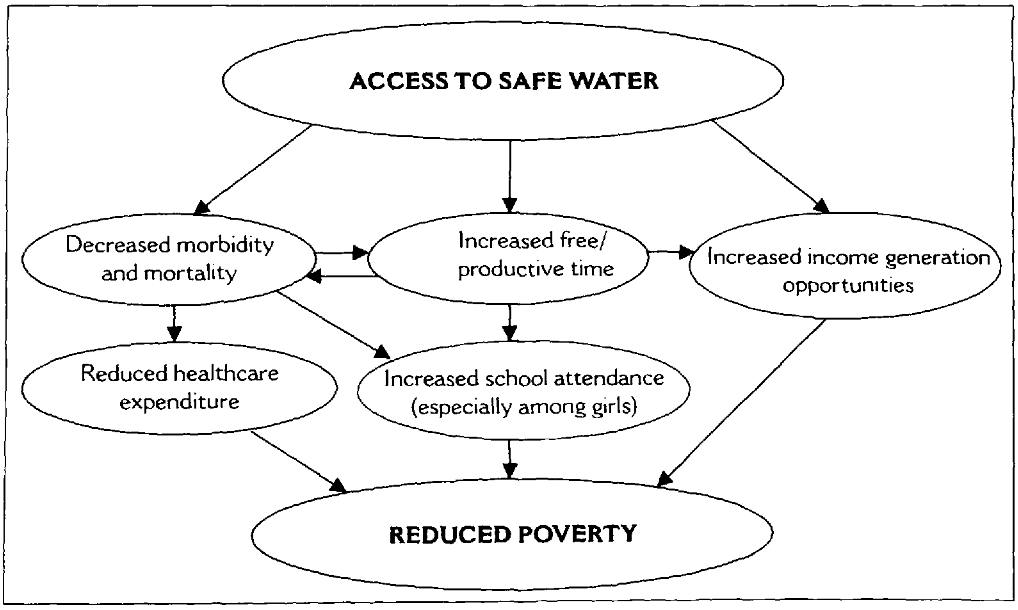


Figure 1 Relationship between water and poverty

be given to the reduction of rural poverty, and consequently, the importance of sustainable service provision in rural areas.

1 Water service sustainability

The Millennium Development Goal (MDG) for environmental sustainability, agreed by the United Nations, includes the target to halve by the year 2015 the proportion of people without sustainable access to safe drinking water (Annan, 2000). If this target is to be achieved, it is estimated that approximately 184 million more people in rural Africa must gain access to safe drinking water before 2015 (UNDP, 2003). In addition to increasing access through implementation of improved water supplies, it is also necessary to ensure that both new and existing water systems are sustainable, so that access to safe water is sustained for all. It is estimated that 35–50 percent of rural water systems in sub-Saharan Africa are not functioning (Baumann, 2005; Harvey and Reed, 2004). Many of the reasons for these low levels of sustainability are related to water user communities, such as limited demand, lack of affordability or acceptability among communities, perceived lack of ownership, limited community education, and limited sustainability of community management structures (Carter *et al.*, 1999). However, there are also many factors external to the community that influence sustainability; these include supply chains for equipment and spare parts, government support, and environmental issues. Figure 2 represents a prognosis model which demonstrates that unless current sustainability levels are increased, even with vastly increased investment for new infrastructure, the MDG target for water will not be realized.

In order to address the critical issue of water service sustainability it is necessary to take a holistic approach which incorporates financial, institutional and community issues, and technological and environmental considerations; all of which are influenced heavily by government policies. The institutional framework is generally defined by government policy which dictates stakeholder roles and responsibilities, be they governmental, private sector, community-based or civil society. Similarly, financing mechanisms for cost-recovery and ongoing operation and maintenance of systems are often defined by sectoral policies. Even the choice of water supply technology is affected by government standardization policies. This is particularly apparent with the handpump-equipped well or borehole which remains the predominant water technology in rural Africa (Narkevic, 2005). In addition, there are many generic policies which have

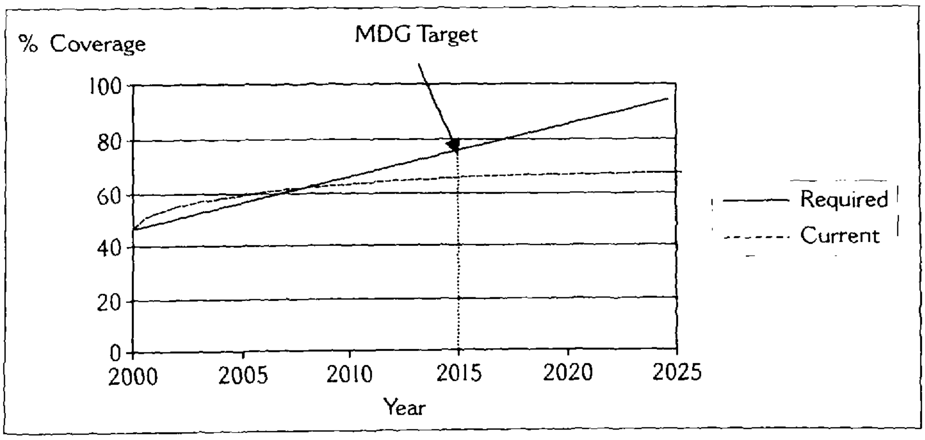


Figure 2 MDG prognosis model illustrating the 'sustainability gap'

indirect but significant impacts on service sustainability, as will be outlined in this paper.

2 Poverty reduction strategies

The World Bank and International Monetary Fund (IMF) launched the Poverty Reduction Strategy (PRS) initiative in 1999. As part of this process low-income borrower countries are required to complete a PRS paper (PRSP) to access Bank and IMF concessional lending and Highly Indebted Poor Countries (HIPC) debt relief. PRSPs are prepared by the government of the member country in collaboration with the staff of the World Bank and IMF, as well as civil society and development partners. These documents describe the country's macroeconomic, structural and social policies and programmes to promote growth and reduce poverty, as well as associated external financing needs and major sources of financing.

According to IDS (2000), the principles that guide PRSPs are:

- *Country-driven:* with governments leading the process and broad-based participation in the adoption and monitoring of the resulting strategy;
- *Results-oriented:* identifying desired outcomes and planning the way towards them;
- *Comprehensive:* taking account of the multi-dimensional nature of poverty;
- *Long-term in approach:* recognizing the depth and complexity of some of the changes needed;
- *Based on partnership:* between governments and other actors in civil society and the donor community.

Forty-one countries were included in the PRS initiative, 32 of them in sub-Saharan Africa. Of the African countries, 20 have completed full PRSPs at the time of writing and nine have produced interim PRSPs. The 20 countries with completed PRSPs were included in this study and are as follows:

1. Benin
2. Burkina Faso
3. Cameroon
4. Chad
5. Ethiopia
6. Gambia
7. Ghana
8. Guinea
9. Kenya
10. Madagascar
11. Malawi
12. Mali
13. Mauritania
14. Mozambique
15. Niger
16. Rwanda
17. Senegal
18. Tanzania
19. Uganda
20. Zambia

In sub-Saharan Africa in general, the water and sanitation sector has been poorly integrated into PRSP and budgetary processes, contrasting sharply with sectors such as education and health that are lent greater priority in PRSP documentation, and subsequently benefit from larger resource allocations (ODI, 2004). A recent review of the PRS process identified the need for greater focus on infrastructure and rural development in PRSPs (OED, 2004). Given these findings the aims and objectives of the study were designed to incorporate these issues in the PRSP assessment process.

Aims and objectives: This study aimed to analyze the contents of PRSPs from the 20 countries to determine the respective emphasis given to water and rural development, and to identify common themes that influence rural water service sustainability. These themes were then analyzed to determine potential opportunities for, and threats to, increased service sustainability. Given the direct relationship between access to water and poverty reduction, the findings were then applied to evaluate the effectiveness of PRSPs for alleviation of rural poverty in sub-Saharan Africa.

II Methodology

The first step in this process was to assess each of the 20 poverty reduction strategy papers in relation to the following factors:

- emphasis on water supply in relation to health and education sectors;
- emphasis on rural development; and
- sustainability factors for rural water services.

The relative emphasis on water supply was determined by assessing the paper content allocated to water supply in relation to the paper content allocated to the health and education sectors. The PRSP was deemed to have 'sufficient' water focus only where water supply was allocated at least 75 percent of the content amount (defined by numbers of lines of text) given to the least emphasized of the other two sectors (that is, health or education).

The relative emphasis for rural development was determined using a similar process, by assessing the paper content allocated to rural development in relation to the paper content allocated to urban development. The PRSP was deemed to have 'sufficient' rural focus only where rural development was allocated at least the same content amount (that is, the same number of lines of text) given to urban development.

In addition to the assessment of relative emphasis on water and rural, the PRSPs were analyzed with respect to generic factors affecting rural water service sustainability. These sustainability factors (derived from Harvey & Reed, 2004) were:

- institutional and financial issues;
- community and social issues;
- technology and the environment;
- supply chains and maintenance; and
- monitoring.

The entire content of each strategy paper was reviewed to identify generic themes which have potential influence on any of the above sustainability factors related to rural water services. Each of the themes identified and its relative potential impact on rural water service sustainability was then examined qualitatively with particular reference to research conducted in four African countries with completed PRSPs: Ghana, Kenya, Uganda and Zambia.

III Results and analysis

Figure 3 summarizes the results of the initial analysis of the 20 PRSPs. This indicated that only six out of 20 PRSPs (30 percent) had sufficient focus on water. Even more tellingly, of the 70 percent of PRSPs with insufficient focus the majority did not have even a single paragraph specifically on water. This supports the OED findings and demonstrates the limited attention given to the water sector in relation to other public service sectors in national strategies for poverty reduction.

The analysis also revealed that only 13 out of 20 PRSPs (65 percent) had sufficient focus on rural development. While this demonstrates a greater emphasis than that for water it again supports the OED findings by revealing that rural development is commonly assigned a lower priority than urban development in macroeconomic planning.

In seeking common generic themes related to sustainability factors it was identified that 20 out of 20 PRSPs (100 percent) emphasized each of the following three themes:

- Trade liberalization;
- Privatization; and
- Decentralization.

Each of these themes has potential direct effects on one or more sustainability factor. Trade liberalization has potential effects on technology, supply chains and maintenance; privatisation has potential effects on institutional and financial issues, technology, supply chains

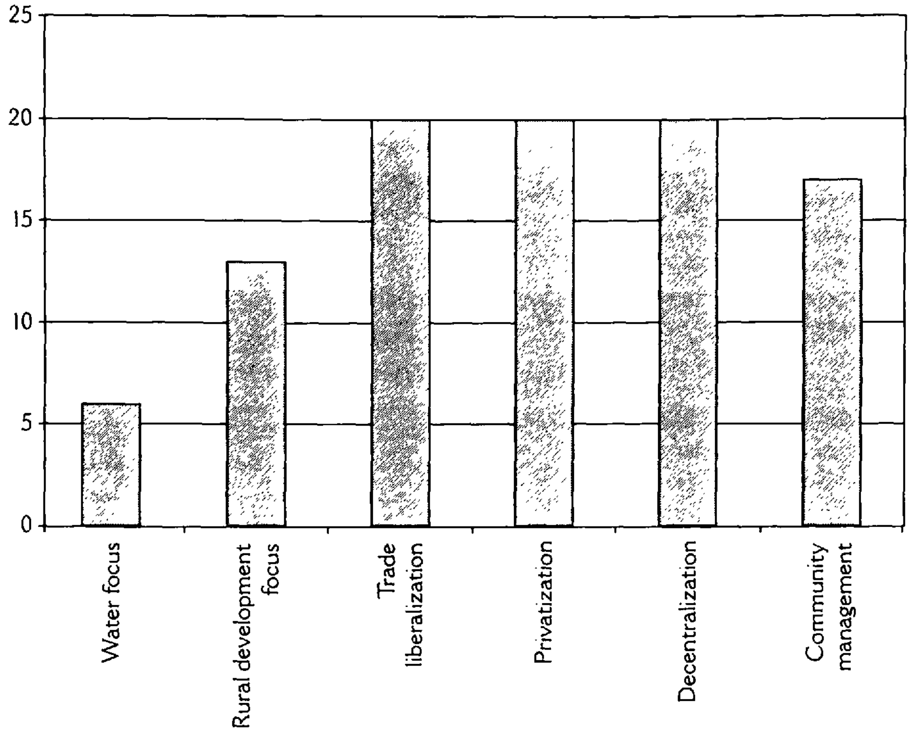


Figure 3 PRSP analysis summary

and maintenance; and decentralization has potential effects on institutional and financial issues, community and social issues, and monitoring.

Of the 30 percent of PRSPs which had sufficient focus on water, all emphasized the importance of community management of rural water supplies. Consequently, the policy analysis was expanded to assess the water sector policies of the remaining 14 countries to ascertain whether these also emphasized community management as a policy directorate. This expanded analysis indicated that 17 countries out of 20 (85 percent) had a clear policy focus on community management, making this a fourth generic theme, since this had a direct effect on community and social issues in relation to rural water services.

Each of the four core themes and how they impact on rural water service sustainability is examined in detail below, with particular reference to the four research countries.

1 Trade liberalization

All of the 20 PRSPs, without exception, emphasize the importance of trade liberalization in reducing poverty. Phrases such as 'liberalising the economy' (Mali), 'open(ing) up trade' (Ghana), 'elimination of barriers to trade and fair competition' (Zambia) and 'continued liberalisation of foreign trade' (Mozambique) are commonplace across country papers. Zambia's PRSP presents the only check on trade liberalization by identifying that 'the introduction of external trade liberalisation with little consideration of the speed and degree to which the country's main regional trade partners are doing the same calls for further reflection'. Even here, however, there is no indication of a significant change in policy direction.

Trade liberalization has specific impacts on rural water service sustainability. Rather than stimulating competition among the private sector and ensuring quality water supply equipment, the policy threatens in-country manufacture and the provision of high quality equipment and spare parts, which are necessary to ensure that water supplies are sustained. Trade liberalization means that local African manufacturers must compete with international companies that benefit from reduced labour wages and increased domestic demand for products within the country of manufacture. Since the vast majority of sub-Saharan African countries have no, or negligible, quality control on imported products, this often means that imported equipment and components are often of lower quality than those manufactured in the country of use. This means there is an increased need for repairs and reduced sustainability.

Local manufacture of handpumps and associated spare parts has considerable potential to promote sustainability of rural water supplies. Indeed, in the 1980s this was thought by many to be a prerequisite for handpump-based water supplies (Arlosoroff *et al.*, 1987) and there was a big drive to promote in-country manufacture which assured quality and accountability. Current evidence suggests that where pumps are manufactured in-country there are significantly fewer problems in setting up sustainable supply chains for equipment and spare parts (Harvey & Reed, 2006). Where pumps are imported, however, there is commonly a lack of quality control and little opportunity for the consumer to exert their rights on the supplier.

An example of this is the case of Uganda (Box 1) in which local manufacture is threatened by uncontrolled importation of often inferior pump components from India.

Procurement processes of governments and major donors exacerbate this problem since pump suppliers are selected on the basis of lowest price per pump and bulk orders for pumps (but not normally spare parts) are placed on this basis. This is in the short-term financial interests of the purchaser but does little to promote sustainability. International companies are keen to compete for contracts to supply large number of pumps, since the profit margins are attractive, but subsequently they have no incentive to supply spare parts which provide negligible profits, and so long as they continue to receive large orders for pumps, business remains viable. This practice means that an isolated supply chain must be set up for the ongoing supply of spare parts, which is an unsustainable private sector activity. Consequently, rural communities have limited access to spare parts and are often unable to repair and maintain their water systems.

The negative effects of trade liberalization are further compounded by import and taxation arrangements imposed by governments. Many international donors and aid agencies have

Box 1 Handpump imports and local manufacturing in Uganda

An indigenous private company manufactures Uganda's standardised handpumps in Kampala. The quality of these pumps is generally good as indicated by the fact that the company received a Quality Award in 2002 from the Uganda National Bureau of Standards (UNBS). The annual sales of the company are about 2,000 handpumps per year although it is capable of manufacturing double this number. There are also several import companies in the country which import near identical pumps from India, which are available at lower prices than those manufactured in Kampala, and are of poorer quality. Due to the Government's policy of trade liberalisation there are no attempts to limit importation of such pumps, which threaten the long-term security and sustainability of local manufacturing, and consequently, the sustainability of rural water services.

(Harvey, 2003)

negotiated with national governments to ensure tax-free aid. This means that import duties and government taxes are commonly waived, supposedly in the interests of 'sustainable development'. In reality, such measures have the potential to completely undermine rural water supply sustainability, since the emphasis is on ensuring low procurement costs for the donor without consideration of the knock-on effects of such a policy. The relaxation of duty on such 'development-related' products means that an uneven commercial playing field is created which disadvantages the local manufacturer. In addition, it also adds to the pumps and spares dichotomy, since duty is commonly imposed on imported spare parts but not on pumps. A clear example of this is the case of Kenya (Box 2).

Despite the negative impacts outlined above, trade liberalization is likely to remain a central tenet of World Bank influenced development policies for many years to come. It is therefore important to recognize potential opportunities it may provide to improve rural water supply sustainability. International competition could improve value for money and cost-effectiveness, but only if national Governments develop effective regulatory frameworks for quality control to prevent the prevalence of inferior products. A community with a pump that constantly breaks down because of poor quality seals will soon decide to stop bothering to repair it and their water supply will not be sustained.

The most important requirement to ensure positive outcomes of trade liberalization, however, is appropriate donor procurement. If agencies that buy pumps for water supply programmes purchase these in the country of use and demand that retailers stock quality pumps and spares, this may promote competition, reduce costs (to agencies and communities) and improve the quality of products. This requires a fundamental change in procurement approach, especially within large international organizations, that decentralizes decision-making powers to national programmes.

Trade liberalization is intrinsically linked with privatization, another central tenet of IMF and World Bank policy, since it encourages free market competition between private enterprises. However, privatization differs in that it has both international and local applications.

2 Privatization

All 20 PRSPs place considerable emphasis on the importance of privatization of national assets and promoting private sector participation in achieving poverty reduction. This has potential for contributing to water service sustainability, but evidence suggests that the current approach to promoting private sector involvement may actually reduce sustainability.

Box 2 Handpump imports and local manufacturing in Kenya

Most NGOs and bilateral agencies in Kenya are exempted from 5 percent import duty and 18 percent Value-Added Tax (VAT) by agreement with central Government. In addition to this, all handpumps imported into the country are exempt from VAT, and importers need only pay the 5 percent import duty. Spare parts and raw materials, however, attract the full levels of VAT and duty. As a result, at least in part, importing large consignments of Afridev handpumps from India proves much cheaper than manufacturing the same pumps in country even though there is capacity to do this. It also means that there is even less incentive to import spare parts, and yet there is insufficient profit to attract local manufacturers to produce these as an isolated activity. There is no Government policy to encourage or protect the local manufacture of handpumps, nor to ensure sustainable spare parts provision.

(Harvey *et al.*, 2003)

The role of the private sector in rural water services in sub-Saharan Africa is largely limited to construction and installation of water systems and the supply of spare parts. Uganda is one country in which the private sector plays a lead role in implementation, since most major donors now provide aid through central budget support and the Government uses private contractors to implement its rural water supply programme (DWD, 2002). This means that increasingly, non-governmental organisations (NGOs), the traditional role of which was to implement donor water supply projects, are becoming largely redundant since donors no longer provide them with funds for direct implementation. This threatens water service sustainability since the main incentive of the private sector is to maximize profits, while that of NGOs is to reduce poverty and ensure sustainable development. Privatization of water and associated services in Uganda is therefore leading once again to a supply-driven approach, in which services are imposed on communities by Governments (in partnership with the private sector) with minimal consideration of their needs and priorities (Harvey, 2003). The Government role is largely limited to contracting out construction works, while most private contractors do not have expertise in community consultation and participation and there are ineffective structures in place to ensure that this happens. Evidence strongly suggests that service sustainability is significantly increased where user communities participate in the decision-making process and implementation responds to their demands (Batchelor *et al.*, 2000).

The privatized approach therefore threatens to negate the gains made by demand-responsive initiatives and to reduce sustainability levels even further, unless there is strong regulation to ensure that poor rural communities are able to articulate their demands and that the private sector responds to these appropriately. Regulation is also essential to ensure that the poorest and most vulnerable people are served adequately and that subsidies are provided for them where needed.

Another major constraint in the push to privatization is the limited capacity of the indigenous private sector in the vast majority of countries of sub-Saharan Africa. Even in Uganda, which is ahead of most other African countries in the privatization process, private sector capacity is generally weak and requires strengthening (NAO, 2003). The slow rate of implementation and lack of competition for drilling contracts for handpump-based water supplies means that the average cost of a borehole in the four detailed study countries is approximately US$ 5,000. This cost is more than five times that of an identical borehole drilled in near identical geological conditions in India (Carter, 2005). The lack of capacity and competition therefore often means lower quality work, resulting in less sustainable boreholes, as well as low cost-effectiveness.

Post-construction private sector participation is generally limited to the provision of spare parts. As discussed earlier, in the vast majority of cases this activity is separated from the provision of pumps which makes it unviable as a stand-alone private sector activity. Selling spare parts is not generally a profitable business and therefore the willingness of the private sector to take on this commercially uninteresting activity is minimal (Baumann, 2000). Evidence from Ghana, Malawi, and Zambia indicates that even when the private sector is persuaded to become involved as a result of incentive provision by donors, supply chains remain unsustainable (Harvey & Reed, 2004). The insistence of donors to continue to attempt to instigate sustainable private sector supply chains for spare parts is irresponsible given the widespread evidence of this lack of viability. A clear example of this is the case of Ghana (Box 3).

The fact that community management of rural water supplies is promoted across Africa, as shall be discussed later in this paper, means that the participation of the private sector

Box 3 Private sector spares supply in Ghana

A joint government/donor initiative in Ghana in 2001 involved a US$125,000 grant to hire a private contractor, rent appropriate warehouses and provide necessary marketing and promotion for a nationwide handpump spare parts supply network. In addition to this, DM 400,000 (US$200,000) was provided to purchase and import the initial batch of spare parts (for all four standardised handpumps found in Ghana) and establish quality control procedures. The intention behind this was for the initial batch of spares to act as a seed fund to generate profits for the private contractor, some of which would be used in a revolving fund to purchase more spares, leading to a fully privatised sustainable supply chain for spare parts.

Despite this considerable investment the private contractor has established only five distribution outlets for spares across the country and does not intend to open any additional outlets due to limited profitability. The location of these existing outlets means that travel from some communities to the nearest retail point takes one or two days and involves considerable cost. The commercial viability, and hence sustainability, of spare parts provision in the country remains seriously doubtful, to say the least, since the use of imported pumps and parts is promoted and yet the demand for and turnover of spares remains very low due to the low density of rural water systems. Private sector stakeholders themselves question the viability of private sector participation and most are reluctant to get involved (Venkatesh, 2002).

(Harvey *et al.*, 2002)

is largely limited to initial construction and provision of spares. Construction contracts are irregular and there is no guarantee of a stable income stream, and provision of spares is commercially unviable. This means that there is currently a serious lack of incentives for private sector participation in rural water services. If privatization is to have a positive impact on service sustainability then public-private options for operation and maintenance (O&M) of water supplies need to be explored. There are several approaches that have been introduced, such as the Total Warranty Scheme in Mauritania (Bernage, 2000) and the Handpump Lease Concept in Angola (van Beers, 2001). These have been successful in providing a regular income to indigenous private sector operators, since rural communities pay them to provide a reliable water service, but have been implemented only on a small scale to date. A recent study in Uganda indicated a strong desire among local spare parts dealers to diversify activities in this way to increase profits (Baumann *et al.*, 2002).

Privatization does provide some opportunities for increased sustainability of rural water services but only if private companies are effectively regulated and if they develop sufficient capacity and skills, especially in community-based development approaches. Indeed, privatized rural water services may provide a more sustainable option than community-managed services, since they are based on sustainable incentives; but interestingly, recent research in Uganda showed that while many staff of Government departments and donor agencies expound the merits of privatized construction of water systems, most are resistant to the idea of privately-run rural water services (Uno, 2005). Whatever level of privatization is adopted, Government regulation is essential. For rural areas this means that Government powers must be decentralized so that regional and district water authorities have sufficient capacity and autonomy to provide effective regulation.

3 Decentralization

The emphasis placed on decentralization varies considerably between the PRSPs of the different countries, yet the move to decentralized service delivery and devolution of power from national level to regional and district levels is inherent in all the papers analyzed. Decentralization provides opportunities for improved local management of water services since greater local government autonomy provides potential for closer links to user communities. This is especially important to provide appropriate support to communities to manage their own water supplies, since in almost all cases community management systems are sustainable only where there is continued local institutional support (Harvey & Reed, 2004). In most African countries the district level is also the optimum level for monitoring and regulation, which is essential to determine whether or not water systems remain operational, and if not, why not, and to ensure that private contractors are operating effectively.

Despite these apparent advantages, decentralization also has a number of potential negative impacts that must be mitigated against if this policy issue is not to result in decreased service sustainability levels. Increased bureaucracy, potential for multiple level corruption and limited capacity have led to increased inefficiencies and decreased sustainability. Uganda and Ghana are ahead of many other African countries in the decentralization process, but in both countries it can be argued that the push to decentralized implementation utilizing the private sector has been too rapid. Local government institutions require time to build up the necessary physical and human resources and develop appropriate institutional mechanisms. This means that efficiencies may be reduced significantly in the transitional phase (Box 4). It remains to be seen, however, whether these inefficiencies will continue or reduce over time. It is clear that local government accountability is essential to ensure that services are provided in an efficient, effective, equitable and sustainable manner.

One contributing factor to the inefficiency observed in Uganda was insufficient capacity of lower levels of Government (at District level and below), especially concerning the ability to mobilize communities to address O&M issues (NAO, 2003). Similar limitations have been identified in Ghana (Harvey *et al.*, 2002) and Kenya (Harvey *et al.*, 2003). Local governments are pivotal to reshaping and strengthening local communities, and intensifying service delivery, especially to the poor, but require capacity building and reflective institutionalization of service delivery instruments (Mogale, 2005).

Of the three themes analyzed so far, decentralization offers the most positive opportunities for enhanced service sustainability levels. Decentralized government authorities are best placed to monitor, regulate and support rural water services. In order to be effective, however, adequate resources must be provided and sufficient capacity developed. This process is likely to take considerable time, but decentralization undoubtedly has the potential to effectively support private service delivery or community managed water services.

4 Community management

Community management is a cornerstone of government policy for rural water services in the vast majority of African countries with PRSPs, and has been consistently promoted by donors and implementing agencies over the

Box 4 Decentralization and privatization in Uganda

In Uganda in 2003, the Ministry of Finance (MoF) undertook an audit of the water supply sector 'Is the Water Sector Performing' in which they asserted that the cost of a single water point had increased by three to four times since the introduction of budget support and decentralised, privatised water service delivery in 2000/01. The Directorate of Water Development of Uganda fiercely rejected the findings of this report, claiming that the data were not reliable, and that there was no urban/rural breakdown considered in the analysis. However, evidence from some NGOs would seem to support the findings of the MoF audit in relation to rural water supplies (Busoga Trust, 2004).

(Harvey, 2003)

past two decades. Despite this uniformity, the policy has undoubtedly had limited success to date, and a number of checks and balances must be instigated if it is to have a beneficial impact on service sustainability.

Community management is based on the well-intentioned principle of empowering communities to take ownership of, and responsibility for, their own water supplies. This is a worthy ideal but the way in which it has been adopted in most countries abrogates responsibility for sustainable service delivery away from Governments and implementing agencies. Since access to safe water is a universal right it is unacceptable and unethical that communities should be left alone to manage and sustain their water supplies, since they may be unwilling or unable to do this. Community management has been adopted by many as a convenient mechanism to 'pass the buck' when it comes to the complex issue of ensuring sustainability. Governments can claim that they are not responsible for rural water services since these are 'community managed'. Implementing NGOs and donors can leave a project area claiming that they have ensured sustainability by 'mobilizing and training' communities to manage supplies themselves. The reality is that many communities do not manage water systems appropriately and that these soon fall into a state of disrepair (Box 5). As already stated, there is a strong need for localized (decentralized) institutional support if community management is to be effective, and yet this is often overlooked. Unchecked, community management may also neglect the poorest and most vulnerable in societies since in most cases there is no systematic way of providing cross subsidy.

It may seem surprising that the major macroeconomic policy of a country (its PRSP) can define the way in which individual rural water supplies are managed, and yet this is the case for some countries in sub-Saharan Africa. Phrases found in PRSPs include: 'emphasis will be given to communities and the users to take responsibility for (water) maintenance works and organisation of management' (Mali); 'communities...to establish lower-level WASHE (Water, Sanitation and Hygiene Education) committees to ensure effective community planning and management of (water) facilities.' (Zambia); 'raising people's accountability for its (water's) management' (Chad); and 'communities... being responsible for the maintenance of facilities' (Uganda). This is a case of policy defining process at a level of detail that seems inappropriate for such a policy paper. It can also be argued that this actually disempowers communities since they are given no choice as to how their water services are to be managed and sustained.

Community management is relevant to the other PRSP themes of trade liberalization and privatization, since if communities are to be primarily responsible for ongoing service provision they are responsible for purchasing spares parts and engaging the private sector. Decentralization is also related as the role of local Government is dependent on how water services are managed. Community management provides significant opportunities for

Box 5 Community management in Zambia

A study of 57 rural communities across 9 districts in Zambia indicated that all communities required a supporting institutional framework at district level to enable them to manage operation and maintenance effectively. Community WASHE (Water, Sanitation and Hygiene Education) committees were most effective where the supporting district WASHE committees were typified by dynamic management and leadership, and included all relevant governmental and NGO stakeholders. In districts where WASHE committees were non-existent, or inactive, the number of dysfunctional community committees, and the proportion of water systems which were not functioning, were 2-3 times higher.

(Harvey and Skinner, 2002)

sustainable water services but whether it is adopted should be decided at local level rather than at national level, based on the wishes of communities themselves. It is also essential that there is clear understanding of what the term 'community management' means; it should not mean that communities can be isolated or that the obligations of Governments can be ignored.

IV Conclusions

This analysis of PRSPs in Africa reveals a high degree of content uniformity despite a significant range in detail and scope. The limited attention to water and rural development in relation to other sectors and urban development indicates that access to water in rural areas is given low priority in reducing poverty. The links between water and poverty are multidimensional and enhanced rural water and poverty focus is required in the PRSP development processes of all countries.

Rural water service sustainability is a dynamic concept which is affected by many interrelated factors. These include trade liberalization, privatization, decentralization and community management, all of which are embodied within the majority of PRSPs. There are strong links between trade and privatization, but for these to have a positive impact on water service sustainability, there must be an even playing field for manufacturers and realistic indigenous private sector opportunities must be developed. If private sector participation is to be limited to construction and spare parts provision, the low levels of rural water sustainability prevalent across the subcontinent are unlikely to improve. Privatization has the potential to increase sustainability but only if the capacity of indigenous private companies is developed and if increased opportunities, such as the opportunity to manage rural water services, are provided for them.

Liberalized trade coupled with donor-friendly import policies and current donor procurement practice does little to enhance sustainability. Trade liberalization can only contribute to service sustainability if the procurement practices of major donors change and if there is effective quality assurance. Donors should buy pumps (whether manufactured locally or imported) in country and should work with private enterprises to ensure sustainable supply chains for pumps and spare parts.

There are also strong links between decentralization, privatization and community management. Decentralization processes must be adequately supported and given sufficient implementation time to ensure development of appropriate resources and mechanisms. If private sector participation is to increase, local government institutions must be equipped to regulate this. Likewise, if communities are to be responsible for management of water supplies they must not be isolated but provided with adequate support from local government. Policy should not dictate management arrangements for water supplies but should be sufficiently flexible to ensure that poor rural communities are provided with real choice and fully empowered.

While there are aspects of PRSPs which have potential to contribute to sustainable water service provision, these must be viewed holistically if these benefits are to be realized. Policy-makers and sector professionals must be made aware of the interrelationships between the PRSP themes identified. Simply promoting 'privatization', 'decentralization' or 'community mangement' means little and may do more damage than good unless the interdependencies between them are understood and practical strategies are developed to maximize their positive impacts.

References

Annan, K. 2000: *"We the Peoples" the role of the United Nations in the 21st century.* United Nations.

Arlosoroff, S., Tschannerl, G., Grey, D., Journey, W., Karp, A., Langenegger, O. and **Roche, R.** 1987: *Community Water Supply: the handpump option.* The World Bank.

Batchelor, S., McKemey, K. and **Scott, N.** 2000: *Exit strategies for resettlement of drought prone populations* (Project Technical Report). Gamos Ltd.

Bernage, F. 2000: *Local private sector involvement: the Mauritania experience.* Paper presented at SKAT/ HTN workshop on Civil Society and Government Partnerships in RWS, Hyderabad, India, March 2000. SKAT.

Baumann, E. 2000: *Water lifting.* Series of Manuals on Drinking Water Supply, Volume 7, SKAT.

——— 2005: *Common RWSN Context.* Discussion Paper. SKAT/RWSN.

Baumann, E., Okuni, P. and **Wandera, S.** 2002: *Supply chains for rural water supply in Uganda.* HTN/SKAT.

Busoga Trust. 2004: *Evaluation of rural water supply programme in Uganda.* Confidential Internal Report. Busoga Trust.

Calaguas, B. and **O'Connell, M.** 2003: *Poverty Reduction Strategy Papers and water: failing the poor?* Discussion Paper, WaterAid.

Carter, R.C. 2005: *Report to 'Groundwater and Poverty Reduction in Africa' symposium.* International Association of Hydrogeologists.

Carter, R.C., Tyrrel, S.F. and **Howsam, P.** 1999: Impact and sustainability of community water supply and sanitation programmes in developing countries. *Journal of Chartered Institution of Water and Environmental Management* 13, 282–96.

DWD. 2002: *Issue Paper 1: overview of the water sector, reform, SWAP and financial issues.* Paper for the Joint GOU/Donor Review for the Water and Sanitation Sector 24-26th September 2002. Directorate of Water Development, Ministry of Water, Lands and Environment, The Republic of Uganda.

Esrey, S.A. and **Habicht, J.P.** 1986: Epidemiological evidence for health benefits from improved water supplies and sanitation in developing countries. *Epidemiology Review* 8, 117–28.

Harvey, P.A. 2003: *Guidelines for sustainable handpump projects in Africa: report on fieldwork in Uganda.* WEDC, Loughborough University.

Harvey, P.A. and **Reed, R.A.** 2004: *Rural water supply in Africa: building blocks for handpump sustainability.* WEDC, Loughborough University.

——— 2006: Sustainable supply chains for rural water supplies in Sub-Saharan Africa. *Proceedings of the Institution of Civil Engineers: Engineering Sustainability* 159, 31–39.

Harvey, P.A., Ikumi, P.N. and **Mutethia, D.K.** 2003: *Guidelines for sustainable handpump projects in Africa: report on fieldwork in Kenya.* WEDC, Loughborough University.

Harvey, P.A., Jawara, D. and **Reed, R.A.** 2002: *Guidelines for sustainable handpump projects in Africa: report on fieldwork in Ghana.* WEDC, Loughborough University.

Harvey, P.A. and **Skinner, B.H.** 2002: *Guidelines for sustainable handpump projects in Africa: report on fieldwork in Zambia.* WEDC, Loughborough University.

IDS. 2000: *Poverty reduction strategies: a part for the poor?* Policy Briefing (Issue 13). Sussex: Institute of Development Studies.

Mogale, T.M. 2005: Local governance and poverty reduction in South Africa (1). *Progress in Development Studies* 5, 135–43.

NAO. 2003: *Department for international development: maximising impact in the water sector.* Report by the Controller and Auditor General HC251 Session 2002–2003: 31 January 2003. National Audit Office.

Narkevic, J. 2005: *RWSN strategy paper: sustainable handpumps.* WSP/RWSN.

ODI. 2002: *Poverty reduction and water: 'Watsan and PRSPs' in sub-Saharan Africa.* Water Policy Brief. ODI Water Policy Programme.

——— 2004: *Towards better integration of water and sanitation in PRSPs in Sub-Saharan Africa: lessons from Uganda, Malawi and Zambia.* WPP Briefing Paper No. 5, ODI Water Policy Programme.

OED. 2004: *OED reach: OED review of the Poverty Reduction Strategy Process.* World Bank Operations Evaluation Department.

UNDP. 2003: *Human development report.* UNDP.

UNICEF/WHO. 2000: *Global water supply and sanitation assessment 2000 report.* WHO/UNICEF.

Uno, J. 2005: *Handpump operation and maintenance by small and medium enterprises: potential in Uganda.* WEDC, Loughborough University.

van Beers, P. 2001: *Leasing, a new handpump O&M concept.* Paper presented at 27th WEDC conference in Lusaka, Zambia, 2001. WEDC, Loughborough University.

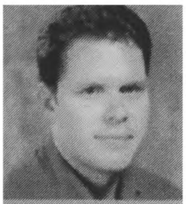
Venkatesh, K. 2002: *Personal communication with the author.* Country Manager, PPSI International Ltd., Accra, Ghana.

2. MANAGEMENT AND INSTITUTIONAL ARRANGEMENTS

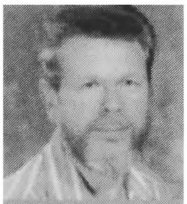
Proceedings of ICE
Civil Engineering 159 November 2006
Pages 178–184 Paper 14569

Keywords
developing countries; management; water supply

Management of rural water services in sub-Saharan Africa


Peter Harvey MSc, PGCE
is a programme manager at the Water, Engineering and Development Centre at Loughborough University


Junko Uno MSc
is a programme officer at the Japanese International Cooperation Agency


Robert Reed MSc, CNNA, MCIWEM
is a senior programme manager at the Water, Engineering and Development Centre at Loughborough University

Rural water supplies in sub-Saharan Africa generally rely on community management and have low levels of service sustainability. This paper reports on a review of rural water supplies throughout the sub-continent including results of field research in Uganda. It reveals that private sector approaches to service delivery have been implemented in a small number of cases but have demonstrated considerable potential for enhanced levels of sustainability. It concludes that the rural African private sector can only develop if decision-makers are prepared to accept the limitations of community management and the need to explore more sustainable alternatives.

Rural water supplies in sub-Saharan Africa demonstrate generally low levels of sustainability with an estimated 35% of all systems out of operation.[1] The primary reason for this is insufficient attention to operation and maintenance of water systems.[2] The currently favoured model of community management, whereby water users are responsible for the management of operation and maintenance, has clearly failed to deliver sufficient levels of sustainability.[3] If the benefits of potable water in poor rural communities are to be realised on a long-term basis throughout Africa, there is a need to develop service delivery models that provide sustainable operation and maintenance. One way in which this may be achieved is to promote greater involvement of the indigenous private sector. However, at present there is a lack of incentives for the private sector to become involved.

This paper investigates the potential

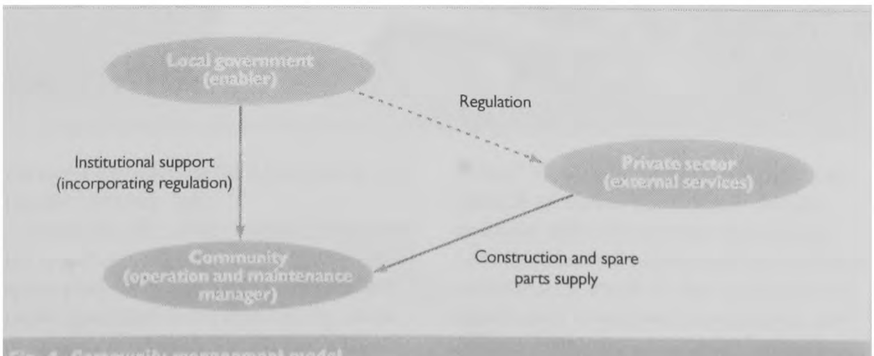


Fig. 1. Community management model

· private sector delivery of rural water
-vices throughout sub-Saharan Africa, th a specific focus on field research in ganda. Rural water supplies utilising nd-pump-equipped boreholes are used illustrate the key issues, since hand imps remain the predominant improved ater supply technology throughout the ıb-continent.[4]

Current service delivery

The current service delivery model ost commonly applied in rural Africa the community management model ig. 1). In this, the role of the private ector is limited largely to the initial onstruction of water systems (Fig. 2) d sometimes the supply of spare parts, hile responsibility for management of ngoing operation and maintenance lies lmost exclusively with poor rural com- iunities. The community management iodel is typified by the following stake- older roles.

- The community is responsible for managing, financing and facilitating operation and maintenance.
- The private sector is responsible for initial construction and the provision of spare parts (though this is sometimes done by government or non-government organisations).
- Local government is responsible for monitoring and regulation, and ideally also provides technical and managerial support to communities (though in reality this is often lacking).

Given the current low levels of service sustainability throughout the sub-conti- ient it cannot be denied that the commu- iity management model has had limited uccess. There are several reasons for his, but perhaps the most apparent is the ack of sustainable stakeholder incentives. Community management commonly relies on voluntary inputs from community nembers, which people may sustain for a while but are reluctant to continue in he long term.[5] Community-based water echnicians such as hand-pump mechan- cs are sometimes paid by the community o conduct maintenance and repairs, but nembers of the committee charged with he management of the water supply are normally expected to fulfil their roles on a purely voluntary basis.

Fig. 2. Private sector borehole drilling in rural Ghana

Fig. 3. Hand-pump spare parts store in Uganda

Since the role of the formal private sector is normally limited to the provision of spare parts (Fig. 3), there is insufficient profit generated from this activity alone to sustain private sector interest and hence supply chains commonly break down.[6] These two factors, coupled with the lack of contact between local government and communities that makes communities feel abandoned and become demotivated, result in the breakdown of community management structures and, consequently, the unresolved breakdown of rural water systems.

Private sector small- and medium-sized enterprises provide a viable management alternative to community-based organisations

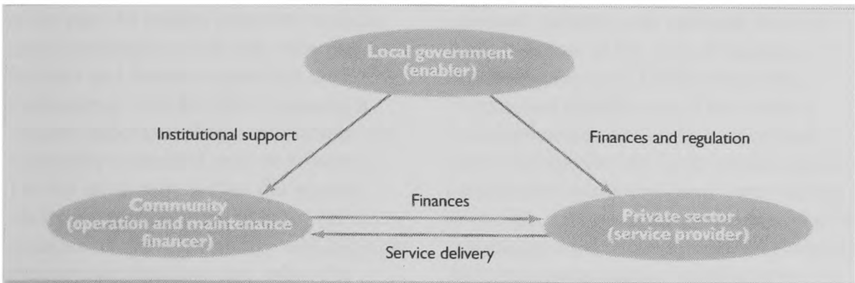


Fig. 4. Private sector service delivery model

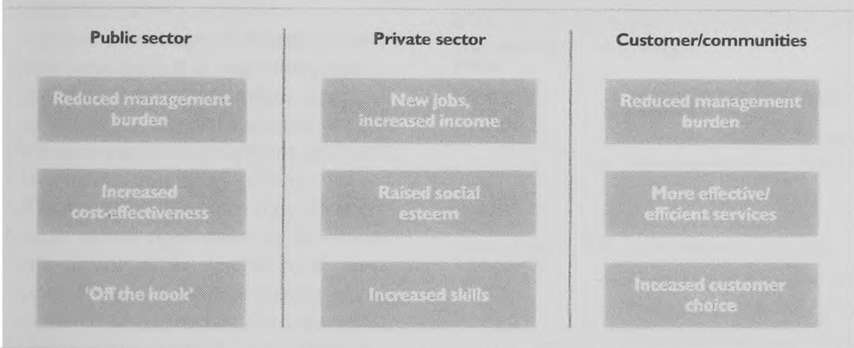


Fig. 5. Stakeholder benefits of private sector service delivery

Fig. 6. Hand-pump repair by private sector contractor in South Africa

Potential for private-sector role

The lack of sustainable incentives provides a strong argument for an increased role for the indigenous private sector. Private sector small- and medium-sized enterprises provide a viable management alternative to community-based organisations. The private sector service delivery model (Fig. 4) is typified by the following stakeholder roles.

- Local government is responsible for monitoring water services and regulation of private sector enterprise (it may also provide subsidies for poorer communities or households if required).
- The private sector enterprise is responsible for the construction, operation and management of water systems, and provision of spare parts and technical services for maintenance and repair.
- The community is responsible for financing service delivery through the payment of appropriate water tariffs (it may also provide cross-subsidies for poorer households).

The model has a number of distinct benefits for all the stakeholders involved (Fig. 5); not least is the increased potential for income and development of indigenous private sector enterprises. The profit motive and raised social esteem provide sustainable incentives for continued private sector participation in maintenance and repair activities to ensure the ongoing delivery of water services (Fig. 6).

There are also several potential benefits to customers living in rural communities. They are no longer required to manage their own water systems, as is the case at present, and consequently they have increased choice, since they can choose whether or not to undertake management responsibilities. Also, competent private sector enterprise performance should lead to more effective and efficient services, particularly where competition develops. The benefits for the public sector are that local government has a reduced management burden, since it acts as regulator only, which should lead to increased cost-effectiveness and also lets government 'off the hook' since comnities will expect a good service from private sector, with reduced expectas of government.

ι potential criticism of the replacent of community management with vate sector management is that it noves power and autonomy from comınities and undermines the gains made the community-centred approaches the past. In reality, however, in most ies communities will still own the :ilities and finance operation and intenance, and for those reasons it nains important that communities are equately consulted and empowered. ie key advantage is that the responility for management is lifted off the oulders of the community which grants em greater freedom and, once the ivate sector becomes well established, eater choice, since they may be able to ιoose their service supplier.

Another advantage of enhanced private ctor participation is that enterprises, ther than rural communities, are sponsible for the procurement of spare ırts and specialist equipment and skills, hich means that supply chains are less fficult to establish since they do not ıve to extend right down to the lowest ommon level of the remote rural comιunity. Private sector enterprises are also ιore likely to appreciate the importance f preventative maintenance, which is oorly understood and rarely practised y communities in low-income countries, nce this will reduce their costs and ıerefore increase profit margins. While ıe capacity of private sector enterprises ı many rural areas is currently limited, ıis can be overcome through technical 'aining and market expansion, as has ccurred in South Africa.[7]

Another potential criticism of privateıanaged services is that the cost of this ; higher than where the community ıanages the service itself, since the 'rivate sector enterprise has to cover its perating costs and make a profit. While nis may be true, a survey of private secor enterprises in Uganda suggests that he likely impact on household tariffs is n increase of 20–40%, of which approxnately 75% would be used in meeting irect operational costs. Such an increase ı cost is within the financial means f most rural communities, since the amount per household is small in relation to household income.

Research suggests that rural households most often cease to pay water tariffs under community-managed systems, not because of an inability to pay, but because of a lack of trust in the management committee.[8] Indeed, where payments are regular and continuous, community management systems may generate revenue well in excess of the cost of operation and maintenance.[9] Tariffs could also be reduced significantly if the number of communities served by each private sector enterprise can be increased significantly with increasing rural water supply coverage. Table 1 summarises the relative advantages and disadvantages of community and private sector management.

Evidence from several African countries indicates that private sector management has significant potential to deliver more sustainable rural water supplies. The 'total warranty scheme', which is essentially a partnership between a pump manufacturer, local after-sales private sector enterprises, local governments and users,[10] has been applied in Mauritania. An evaluation after two years of operation indicated that 80% of communities still regularly paid the private sector enterprises for service delivery and systems remained operational.[11]

Similar examples include the 'membership scheme' in Kenya, whereby member communities are committed to pay a monthly premium to an indigenous private sector enterprise, which manages operation and maintenance and is regulated by local government,[12] and

Management body	Advantages	Disadvantages
Community	Potential for fast initial response to problems Community in control of own affairs Develop pride in own achievements	Needs motivated people Voluntary inputs are difficult to sustain Needs appropriate local skills and tools Difficulty in accessing spare parts Needs government support
Private sector	Easier access to spare parts Concentration of skills and resources Profit creates a sustainable incentive Community choice and freedom	Potentially higher cost Private sector capacity must be built Needs active government regulation

Model	Key characteristics
Total warranty scheme	The manufacturer (of pumps) supports and trains local private sector enterprises to act as its local agents and provides spare parts through them. Water users own their systems and sign a warranty agreement under which they agree to pay an annual premium to a local private sector enterprise, which is responsible for all aspects of maintenance and repair of pumps installed in villages and is regulated by local authorities. Should the private sector enterprise or manufacturer fail in their duties, an alternative manufacturer or supplier is likely to be sought for replacement and future systems.
Membership scheme	Communities own their water systems (which may use different technologies) and are given the option of joining a membership scheme whereby they are committed to pay a monthly premium (based on technology type) to an indigenous private sector enterprise, which is regulated by local government. For as long as the premium is paid, the private sector enterprise provides an annual preventive maintenance and water monitoring service and is responsible for any repairs needed to the water system.
Lease concept	A local private sector enterprise owns a number of water supply facilities (e.g. hand-pumps) and leases these to communities under a signed contract which commits the private sector enterprise to ensure that each water system operates effectively for as long as the monthly lease payments are made. Communities may decide to adopt a payment system whereby users pay a small tariff to the pump caretaker at the point of collection and the revenue raised is used to pay both the private sector enterprise and the caretaker.
Lease-to-buy	A local private sector enterprise finances and owns a number of water supply facilities and leases these to communities under a contract. The lease payments cover the cost of operation and maintenance services provided by the private sector enterprise plus cost-recovery for the water facility itself, which becomes the legal property of the community after several years.

the 'lease concept' in Angola, whereby a local private sector enterprise owns a number of water supply facilities, leases these to communities and ensures that each water system operates effectively for as long as the lease is paid.[13] There is also scope for lease-to-buy models or hire-purchase agreements.[14] Table 2 summarises the key characteristics of each of these models.

Ideally, for all options, local government should regulate private sector enterprises to ensure that tariffs are fair and affordable, and that private sector enterprises adequately fulfil their responsibilities. However, evidence from Angola and Somalia, where local government authorities are largely non-existent, indicates that even where such regulation is not in place, communities and private sector enterprises are able to agree effective operational frameworks.[13,15] To date, none of the models has been implemented on a large scale which makes it difficult to evaluate them fully, but where they have been applied they have resulted in high levels of sustainability and there is no doubt that they have significant potential for expansion. What is required is greater willingness to apply them.

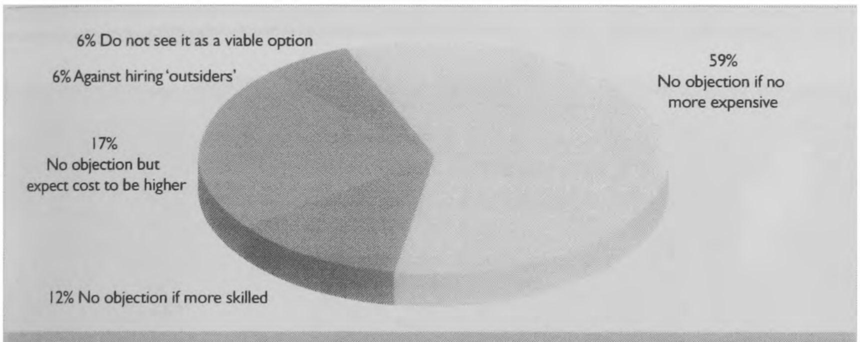


Fig. 7. Community perceptions towards private sector service delivery


Fig. 8. Community-owned water facility in Zambia

Fig. 9. Community perceptions towards ownership of the water system

The field research in Uganda involved a series of interviews with community members, government personnel, private sector enterprises and aid agency personnel at national and district level, in order to identify potential opportunities and key barriers to increasing private sector participation in rural water services.

Informal interviews and focus group discussions were held with community members in a representative sample of rural communities which revealed that an overwhelming majority of 88% of all communities had no fundamental objection to private sector service delivery in place of community management, although there were concerns about cost (Fig. 7). While government policy in Uganda does not preclude private sector service delivery—indeed privatisation is a central tenet of the country's poverty eradication action plan[16]—75% of government interviewees saw no advantage in private sector participation and all interviewees claimed that community management was fundamental to sustainable rural water provision, even while conversely accepting that current sustainability levels were unsatisfactory.

A general suspicion of the profit-oriented nature of the private sector and arguments that the indigenous private sector has insufficient capacity to perform the necessary tasks were the most commonly cited reasons for dismissing its involvement. A limited number of interviews with aid agency personnel engaged in rural water supply activities in Uganda

Fig. 10. Small rural water supply enterprise in Kenya

evealed a similar viewpoint. While there /as no fundamental objection to private ector participation, a strong belief in the nportance of community management vas expressed, as was the viewpoint that t simply requires more time to be imple- nented successfully.

All government and aid agency ersonnel interviewed believed strongly hat water supply systems should be wned by rural communities themselves Fig. 8). This was backed up by 94% of ommunities, which expressed a desire to etain ownership of their water systems Fig. 9). This suggests that the replacement f community management with private ector management will only be successful f communities retain ownership of their vater supplies. This would also mean hat communities would have the option f opting out of private sector systems nd returning to self-management should hey so wish. Interviews with private sector enterprises in rural townships and growth centres revealed that the primary motivation for participation was profit, although the expected annual return on investment varied considerably from 10–50%, most interviewees expressing a desire simply to make a reasonable living.

Social welfare or esteem within the community were recognised but not deemed sufficient incentives alone to sustain involvement. Private sector enterprises which were already engaged in activities related to water supply, such as installing pumps or selling spare parts (Fig. 10), expressed a much stronger desire to become involved in water service delivery than those operating in less closely related sectors such as agriculture. Many private sector enterprises recognised the need for initial government support to attract private sector participation and to build capacity through technical training.

Communities also recognised the important role that government would need to play for private sector service delivery to be viable, with 72% of communities consulted believing that long-term financing for asset replacement and rehabilitation should come from government (Fig. 11) and 31% believing that government should have a role in setting water tariffs (Fig. 12). This suggests that government regulation (and where required, subsidy) should ideally be an integral part of private sector management models.

User communities do not have an inher- ent resistance to private sector manage- ment of services, but the cost of services is a key determinant in their choice of model. The negative perceptions of gov- ernment and aid agency personnel are one of the principal barriers to indigenous private sector participation in rural water service delivery.

Communities place importance on self-ownership of their own water systems but are less concerned about who manages systems. Private sector management models are likely to be most successful where the community retains ownership of its water supply.

The indigenous private sector in many parts of rural Africa currently has limited capacity and government support may be required initially to build private sector enterprise capacity, stimulate participation and develop local markets. Private sector management of rural water services in sub-Saharan Africa remains uncommon, but where it has been applied it has been relatively successful since it is built on sustainable stakeholder incentives.

There is an apparent need for decision-makers to accept the limitations of community management and the need to explore sustainable alternatives, including increased private sector participation.

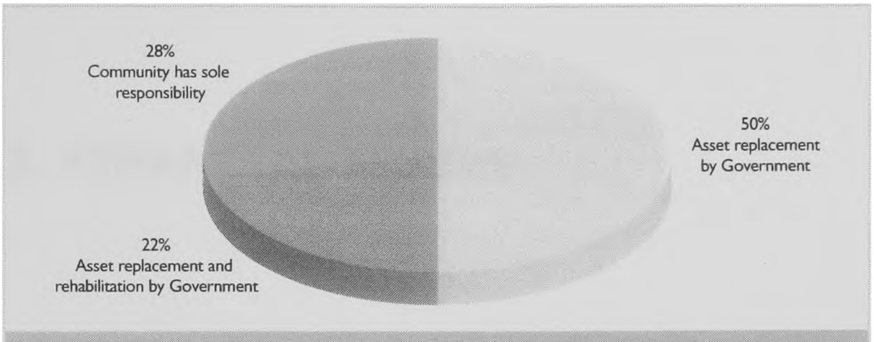


Fig. 11. Community view on responsibility for long-term financing

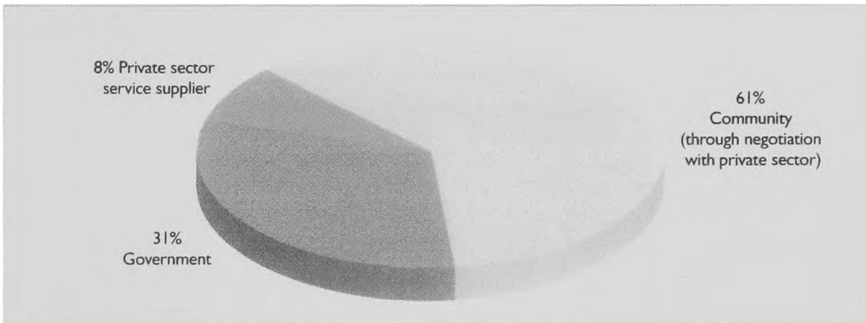


Fig. 12. Community view on who should set water tariffs

References

1. BAUMANN E. *Common Rural Water Supply Network Context.* SKAT, St Gallen, Switzerland, 2005, discussion paper.
2. WORLD HEALTH ORGANISATION. *Tools for Assessing the O&M Status of Water Supply and Sanitation in Developing Countries.* WHO, Geneva, Switzerland, 2003, 46 pp.
3. WATER SUPPLY & SANITATION COLLABORATIVE COUNCIL. *Beyond the Community.* E-conference on Scaling up of Community Management of Rural Water Supplies, WSSCC, Geneva, Switzerland, 2002.
4. NARKEVIC J. *RWSN Strategy Paper: Sustainable Handpumps.* Water and Sanitation Program/Rural Water Supply Network, Nairobi, Kenya, 2005.
5. CARTER R.C., TYRELL S.F. and HOWSAM P. Impact and sustainability of community water supply and sanitation programmes in developing countries. *Journal of the Chartered Institute of Water and Environmental Management,* 1999, **13**, No. 3, 292–296.
6. HARVEY P.A. and REED R.A. Sustainable supply chains for rural water supplies in Africa. *Proceedings of the Institution of Civil Engineers, Engineering Sustainability,* 2006, **159**, No. 1, 31–39.
7. HARVEY P.A. and KAYAGA S.M. *Sustainable Handpump Projects in Africa: Report on Fieldwork in South Africa.* Water, Engineering and Development Centre, Loughborough University, UK, 2003.
8. HARVEY P.A. and REED R.A. *Rural Water Supply in Africa: Building Blocks for Handpump Sustainability.* Water, Engineering and Development Centre, Loughborough University, UK, 2004.
9. HARVEY P.A., JAWARA D. and REED R.A. *Sustainable Handpump Projects in Africa: Report on Fieldwork in Ghana.* WEDC, Loughborough University, UK, 2002.
10. PARRY-JONES S., REED R.A. and SKINNER B.H. *Sustainable Handpump Projects in Africa: A Literature Review.* Water, Engineering and Development Centre, Loughborough University, UK, 2001.
11. BERNAGE F. Local private sector involvement: the Mauritania experience. *Proceedings of a SKAT HTN Workshop on Civil Society and Government Partnerships in RWS, Hyderabad, India, March 2000.* SKAT, St Gallen, Switzerland, 2000.
12. HARVEY P.A., IKUMI P.N. and MUTETHIA D.K. *Sustainable Handpump Projects in Africa: Report on Fieldwork in Kenya.* Water, Engineering and Development Centre, Loughborough University, UK, 2003.
13. VAN BEERS P. Leasing, a new handpump operation and maintenance concept. In *Proceedings of 27th WEDC Conference, Lusaka, Zambia,* August, 2001 (SCOTT R. (ed.)). Water, Engineering and Development Centre, Loughborough University, UK, 2001.
14. SARKINNEN P. *Lessons Learned from Kenya–Finland Western Water Supply Programme (1981–1993).* United Nations Development Program–World Bank Regional Water and Sanitation Group, Washington DC, December 1994.
15. UNITED NATIONS CHILDREN'S FUND. *Water and Environmental Sanitation Workshop for UNICEF East Africa.* UNICEF, Nairobi, Kenya, 2006.
16. MINISTRY OF FINANCE, PLANNING AND ECONOMIC DEVELOPMENT. *Uganda's Poverty Eradication Action Plan: Summary and Main Objectives.* MFPED, Government of Uganda, Kampala, March 2000.

What do you think? If you would like to comment on this paper, please email up to 200 words to the editor at editor@ice.org.uk.

If you would like to write a paper of 2000 to 3500 words about your own experience in this or any related area of civil engineering, the editor will be happy to provide any help or advice you need.

3. FINANCIAL ISSUES

Water Policy 9 (2007) 373–391

Cost determination and sustainable financing for rural water services in sub-Saharan Africa

Peter A. Harvey

Water, Engineering and Development Centre (WEDC), Institute of Development Engineering, Loughborough University, Loughborough, LE11 3TU, UK. Tel: 01509-228743, Fax: 01509-211079. E-mail: P.A.Harvey@lboro.ac.uk

Received 19 December 2005; accepted in revised form 29 March 2006

Abstract

Access to safe, sufficient and affordable water in rural Africa will not increase unless sustainable financing strategies are developed which ensure the sustainability of existing water services. There is a strong need for international donors and national governments to confront the true costs associated with sustained service provision in order to develop practicable long-term financing mechanisms. This paper presents a systematic approach that can be applied to determine the overall cost of service delivery based on respective cost estimates for operation and maintenance, institutional support, and rehabilitation and expansion. This can then be used to develop a tariff hierarchy which clearly indicates the cost to water users of different levels of cost recovery, and which can be used as a planning tool for implementing agencies. Community financing mechanisms to ensure sustained payment of tariffs must be matched to specific communities and their economic characteristics; a blanket approach is unlikely to function effectively. Innovative strategies are also needed to ensure that the rural poor are adequately served, for which a realistic, targeted and transparent approach to subsidy is required.

Keywords: Africa; Developing countries; Financing; Rural water supply; Sustainability

Introduction

In the year 2000, the United Nations, through the Millennium Development Goal (MDG) for environmental sustainability, set the international target to halve the proportion of people without sustainable access to safe drinking water by the year 2015 (Annan, 2000). Estimates of the annual investment required to finance this target vary enormously, but the majority are almost certainly underestimates since they do not account for maintenance and rehabilitation of existing infrastructure, nor consider the costs of maintaining the institutions and support services required for service sustainability (Fonseca & Cardone, 2004).

doi: 10.2166/wp.2007.012

Rural sub-Saharan Africa has the lowest water service coverage of any region in the world at 45% in the year 2002; if current trends continue the MDG target will not be met, primarily because of conflict and political instability, high population growth rates and low priority given to water and sanitation (WHO/UNICEF, 2004). This major challenge is exacerbated by limited sustainability of existing rural water systems, with an estimated 35% of systems in sub-Saharan Africa being out of operation at any given time (Baumann, 2005). Before ambitious coverage targets can be considered, it is essential that both existing and new rural water services are sustained. One of the main reasons for poor levels of sustainability is the prevalence of unacceptable, unaffordable or impracticable financing strategies (Carter *et al.*, 1999). The development of sustainable financing mechanisms is therefore imperative to ensure sustainable service provision. This cannot be achieved unless realistic long-term costs are determined. There has been far too little attention given to this issue by donors, governments and implementing agencies in the past, and consequently few countries have realistic policies, operational strategies or plans for sustainable financing for increased service coverage, particularly for the poor (Fonseca, 2003).

The current situation has arisen primarily owing to the policies and practices of international donors and western development agencies. The development project approach adopted has provided a convenient concept to abrogate responsibility for long-term service provision from implementing agencies, be they non-governmental organizations (NGOs), bilateral agencies or governmental authorities, to poor rural communities. The presumption that once a new water supply is constructed and "handed over" to the user community it can be sustained by community financing of operation and maintenance (O&M) is over-simplistic, especially since the long-term O&M costs are neither calculated nor communicated to water users. This simplistic approach is reflected in the western-influenced policies and strategies of many African countries. A brief analysis of the 20 sub-Saharan African countries with completed poverty reduction strategy papers (PRSPs) reveals that 85% of those countries have an emphasis on community management and financing of rural water supplies in key national strategy documents, yet these do not adequately address the determination, nor affordability, of associated costs. If this does not change then sustainability levels will remain unacceptably low and the proportion of people without access to safe drinking water in rural Africa will remain unacceptably high.

This paper, based on research on sustainability of rural water services in sub-Saharan Africa, with a particular focus on Ghana, presents a systematic approach that can be used to estimate the true cost of sustainable service delivery to the consumer. It also identifies potential financing mechanisms which ensure service sustainability for the rural poor.

Cost recovery

The term "cost recovery" is routinely referred to in rural water projects and programmes but can be applied in many different ways. In general, cost recovery refers to the practice of charging users the full (or nearly full) cost of providing services (MacDonald & Pape, 2002). Full cost recovery means reimbursement to service providers of both recurring and non-recurring costs associated with construction, management, O&M, rehabilitation and expansion of water systems. Costs include, but are not limited to, the costs of community mobilization, planning, design, administration, construction and O&M. Full cost recovery for rural water services in Africa is rarely, and probably never, achieved because:

- the cost of systems is significantly beyond the means of most rural communities; and

- the political and humanitarian desire for improved access to water, and definition of water as a "right", mean implementers are reluctant to seek full reimbursement.

Whereas during the Second World Water Forum in 2000 full cost recovery was advocated, during the Third Word Water Forum in 2003 the concept of sustainable cost recovery emerged, in which the general necessity for subsidies, especially for the poor, was acknowledged (World Water Council, 2004). Whilst it is generally agreed and widely accepted within the donor community that users should pay for operation and maintenance costs, there is no consensus on whether users should pay for capital costs and if so, what percentage is reasonable and how might it be paid (Fonseca & Njiru, 2003). Cost recovery for construction and installation of new rural water systems and facilities is, in practice, negligible. Communities are often requested to contribute 5 to 15% of initial capital costs, which usually means the cost of the water facility itself (e.g. a hand pump installed on a borehole). The costs of mobilization, administration, management and transportation generally remain hidden. Even where communities are expected to make a financial contribution, this is commonly intended to demonstrate demand, instil a sense of ownership and act as an indicator of the community's ability to organize and collect payments, rather than a real attempt to recover actual implementation costs (Deverill *et al.*, 2002). It is generally accepted that user financing of full implementation costs for improved rural water systems is an unrealistic goal. In a rural African context, therefore, the infrastructure development required to ensure increased access to water is likely to remain dependent on external donor support or continuous national government investment (Lane, 2004).

Cost recovery for ongoing service delivery and recurrent O&M costs may be a more achievable target, but evidence suggests that the majority of community organisations and small service providers are failing to generate sufficient revenues even to meet the direct O&M costs of existing systems (Fonseca, 2003). Direct O&M costs comprise those for maintenance, repair and asset replacement. Even where cost recovery for O&M is relatively high this rarely reaches 100%, owing to hidden costs such as subsidy of spare parts provision, supply chains and institutional support from local government or aid agencies (Harvey & Reed, 2004).

Ideally, the water tariffs that users pay should cater for future system upgrade, rehabilitation and expansion costs, as well as ongoing O&M costs. Currently, this occurs very rarely, if ever. One of the main constraints is the need for a transparent, secure and sustainable method of storing and investing money for future use. Community-managed financing mechanisms are rarely able to fulfil these requirements. Private sector service providers could potentially do this but require sufficient incentive and regulation. The second key constraint is insufficient ability and willingness to pay for these costs among users. In many cases it may be unrealistic to expect poor rural communities to finance these costs and this highlights the need for an external institution (ideally local government) to provide appropriate support. This also applies to emergency needs, such as the results of sabotage or natural disasters.

The term cost recovery as applied to rural water services remains generally misleading, since capital costs are simply not recovered, and even where direct O&M costs are met by users, revenues are generally insufficient to recover indirect costs such as the cost of developing adequate institutional capacity to provide support. The term "sustainable financing" is therefore used in this paper since this better articulates the need to "pay for water", i.e. finance the cost of ongoing provision of a water service on an indefinite basis.

Cost determination

Determination of the real costs of service provision is one of the key problems in developing sustainable financing strategies (Fonseca & Njiru, 2003). Most implementing agencies simply do not address this issue adequately, in part because there is a lack of systematic guidelines to estimate costs. Without comprehensive cost determination, however, it is impossible to inform water users of the true cost of service sustainability to them, or to determine the level of external financial support that may be required. If sustainable financing mechanisms are to be developed, so that rural water services are to be sustainable, the following three categories of cost must first be calculated:

- direct O&M costs;
- indirect O&M costs (institutional support costs) and
- rehabilitation and expansion costs.

Costing operation and maintenance

The main consideration when determining direct O&M costs for rural water systems is to incorporate recurrent repair costs and future asset replacement costs. Without considering the need for saving specific sums of money to replace major component parts, the sustainability of most water systems is undermined. One method that can be used to do this is *amortization* whereby equal amounts are set aside every year, taking into account interest rates. These amounts can form part of the O&M tariffs charged. A four-stage process that can be used to determine appropriate tariffs is outlined below. The India Mark II hand pump is used as an example to illustrate the process. This was selected since hand pumps remain the principal technology for improved rural water supplies in sub-Saharan Africa (RWSN, 2005) and the India Mark II is one of the most common public domain hand pumps, which has been adopted as a "standardized" pump in several African countries, including Ghana. It is accepted that there are many other rural water technologies in addition to the conventional hand pump, and the process developed, as presented here, can also be applied to them.

1. *Recurrent O&M costs*: the first step is to calculate recurrent O&M costs, which include replacement of minor components and routine preventive maintenance, and any wages associated with these. Table 1 gives an example of components, costs and estimated frequency of replacement for an India Mark II hand pump. The total annual cost of components, C can be determined by dividing each unit cost by the estimated frequency of replacement and summing these.

The annual cost of components may vary considerably, even for the same technology, and depends on the local environment. For example, hand pumps operating in areas of deep, aggressive (low pH) groundwater which are subjected to heavy usage, may have much higher O&M costs than those operating in shallow, neutral conditions with low usage. The only reliable way to obtain guidance for costs in specific local conditions is through appropriate monitoring.

Once the total annual cost of components, C, is determined the annual maintenance cost, M, can be determined by adding the required labour and transportation cost, L. This will vary depending on the local economy and type of maintenance system utilised.

$$\begin{aligned}\text{Annual maintenance cost, } M &= \text{Annual cost of components, } C \\ &\quad + \text{Labour/transport costs, } L \end{aligned} \tag{1}$$

Table 1. Example of recurrent O&M component costs for an India Mark II hand pump[a].

Component	Estimated frequency of replacement, f (year)	Unit cost, U (US$)	Annual cost, U/f (US$)
O-ring seal	2	1.60	0.80
Cup leather	2	1.00	0.50
Chain	3	3.60	1.20
Handle axle	3	6.00	2.00
Axle bearing	3	7.50	2.50
M12(10 nut	1	1.50	1.50
M12(50 nut	1	1.50	1.50
Foot valve rubber	3	6.00	2.00
Piston valve rubber	2	1.00	0.50
Grease	1	2.50	2.50
Total annual cost of components, $C =$			20.00

[a] Based on data from Ghana. This is an example only; f and U will depend on local economy, quality and age of equipment, environmental conditions and usage pressure.

Using the example in Table 1 and average figures obtained in Ghana, assuming the area pump mechanic has to make an average of two visits per year and charges US$5.00 per visit, plus US$2.50 for transportation, the total annual cost of labour and transportation is US$15.00. Therefore:

$$\text{Annual maintenance cost, } \mathrm{M} = \mathrm{C} + \mathrm{L} = 20.00 + 15.00 = \mathrm{US\$}35.00 \tag{2}$$

Since the costs are relatively low and are set in hard currency, any inflationary increases are not considered since these are likely to be negligible.

2. *Current replacement costs*: the second step is to calculate the current replacement costs and the projected lifespan of major components which are likely to need to be replaced. Depending on the technology and environment this may be based on the replacement of the entire facility (e.g. hand pump) or specific components of that facility. Table 2 gives an example of the major components of an India Mark II hand pump which may need replacing after a five-year period of use, and their respective costs.

Once calculated, the estimated replacement cost should be compared to the total current cost of a complete facility. For example, in some cases the cost of a complete hand pump may be lower than or similar to that of the component parts, particularly where pumps are ordered in bulk. If this is the case the entire hand pump could be replaced after five years rather than the major components listed.

The current replacement cost, R is the current cost of complete facility or major components and n is the estimated number of years before replacement. The value of n may be greater than 5 and will depend on the particular technology, model, manufacturer and conditions under which it is operating.

3. *Annuity*: the next step is to calculate the annual amount or *annuity* which needs to be put aside each year to meet future replacement costs. This is based on an annuity factor (AF), which is a function of the expected lifespan of the equipment in years (n) and the interest rate (r) in the local economy (Wedgwood & Sansom, 2003). This does not consider inflation but allows for devaluation, which is especially important for imported components and overrides inflation effects in many developing countries. The following equation can be used:

$$\text{Annuity, } A = \frac{\text{Current replacement cost, } R}{\text{Annuity factor } (AF_{\mathrm{r,n}})} \tag{3}$$

Table 2. Example of 5-year replacement costs for an India Mark II hand pump[a].

Component	Unit cost (US$)
Hand pump cylinder	115.00
Foot valve	8.00
Hand pump tank	22.00
Hand pump head	81.00
10 Connecting rods	80.00
Apron and drainage repairs	30.00
Total replacement cost, $R =$	336.00

[a] This is an example based on data from Ghana, which identifies components requiring replacement five years after installation, assuming that stainless steel riser pipes are used. Where galvanised iron pipes are used which are likely to be subject to corrosion, these should be included in the cost estimate.

Annuity factors are based on number of years and interest rates and can be read directly off financial cost tables. In order to adjust for inflation the annuity can be multiplied by the cumulative inflation rate.

4. *Average annual cost of O&M*: the final step is to calculate the average annual cost of O&M per household. Ideally, the annual amount paid each year (or saved in a communal/private fund) should be slightly higher than the calculated annuity to allow for unforeseen events and inflation. A contingency factor of 20% can be used to compensate for this and will ensure that the users have saved enough to compensate for future price changes for the required component. The household tariff per year, H, can be estimated using equation (4), where N is the number of households in the community:

$$\text{Annual household tariff, } H = 1.2\left[\frac{M+A}{N}\right] \tag{4}$$

This is based simply on the total number of households using the facility. To ensure equity, household tariffs can be modified by three factors: the distance from the source, the number of people in the household and "special" factors such as poverty or disability (Deverill *et al.*, 2002). Box 1 gives a worked example for a hand pump water supply.

The household tariffs calculated for low-cost community water systems, such as hand pumps and gravity-fed systems, are generally very low and normally below US$0.50 a month (Harvey & Reed, 2004). The process above can be repeated after five years to assess whether an increase in tariff is required based on the costs at that time. Alternatively, tariffs may be calculated for a twenty-year period from the start of the service, accounting for repeated replacement of major components and/or pumps. Ongoing monitoring and regulation is essential to make appropriate adjustments for changing circumstances. The above process does not include costing for rehabilitation and expansion.

Costing institutional support

The assumption that supporting community-based O&M is a less onerous task than running a centralized maintenance system has not been borne out in the field (WHO, 2000). In recent years there has been a growing awareness and acceptance of the need to provide institutional support for

Box 1 Example of household tariff setting for a hand pump water supply

Using the example for the India Mark II hand pump above:

Total annual maintenance cost,	$M = \$35$
Current replacement cost,	$R = \$336$
Estimated number of years before replacement,	$n = 5$ years
Approximate interest rate,	$r = 20\%$
Annuity factor (read from table)	$AF_{r,n} = 2.83$
Annuity, $A = R/AF_{r,n} = 336/2.83 =$ US\$119	
Number of households,	$N = 50$ (300 people)
Annual household tariff, $H = 1.2\left[\frac{M+A}{N}\right] = 1.2\left[\frac{35+119}{50}\right] =$ US\$3.70	

This can then be divided by 12 to convert to a monthly household tariff of US$0.30.

community-based management systems (Schouten & Moriarty, 2003). Appropriate institutional support comprises the following components:

- encouragement and motivation
- monitoring and evaluation
- participatory planning and regulation
- capacity building and
- specialist technical assistance (including financial support where required).

Such support obviously has an ongoing cost associated with it and although this has been largely ignored in the past, some governments are now attempting to address this. Nedjoh *et al.* (2003) cite the case of the Volta Region of Ghana where local government institutions earmark 6% of investment funds to increase access to rural water supply for monitoring and O&M of all new and existing systems. This is based on an ongoing programme to construct 100 new water points per annum, in an area with 500 existing water points. Obviously, institutional costs will vary considerably from location to location and it may be that a direct relationship with expansion investment is not always appropriate. It is essential, however, that the cost of institutional support is estimated and that appropriate budgetary allocation is made for this. Table 3 presents an example breakdown of costs for institutional support which shows the aspects which should be considered and estimated cost ratios for these. These costs are based on consultation with government agencies and NGOs in Ghana and are indicative only.

The above costing example equates to US$100 per supported community per year. Such a cost should not be excessive to a local government authority and for 100 communities is roughly the cost of one hand pump-equipped borehole in many African countries. The figure quoted could be reduced considerably further where institutions support a greater number of communities, where communities develop increased self-sufficiency, or where support from other stakeholders (e.g. non-profit organizations) is available. What is vitally important is that institutions attempt to estimate costs and budget accordingly.

Support costs need to be determined locally and appropriate long-term funding mechanisms sought. If full-cost recovery were to be realised from users, communities would also be expected to meet the cost of institutional support. Using the example of the hand pump water supply in Ghana, this would result in a tariff increase of 100% for an average community of 300 people. It would also mean that they would be required to pay this increase in taxation to local authorities, which would require the establishment of

Table 3. Example breakdown of costs for institutional support.

Activity	Annual cost per 100 communities (US$)
Monitoring and evaluation: quarterly monitoring visits to all communities	3,000
Participatory planning and regulation: liaison with problem communities and CBOs to develop solutions	2,000
Specialist technical assistance: advice and intervention for unforeseen technical problems	2,000
Capacity building: training of stakeholders (staff, communities, private sector etc.)	3,000
Total annual cost per 100 communities =	10,000

community-based organisations (CBOs) as legal entities and an effective regulatory framework. This remains a far-off goal at present and it is difficult to envisage CBOs ever agreeing to pay local government a proportion of the revenue raised from water users, particularly as there is often a traditional expectation that government should provide water services free-of-charge. The reality is that local government institutions need to develop budgets which recognize the need for such expenditure on a long-term basis.

Even where water supply management systems are not community based, institutional support costs are likely to remain at similar levels. In public-private models community-based support costs would be replaced with those related to regulation of the private sector. The added advantage of this model is that taxation of the private sector has the potential to contribute to funding this support. Although the cost of this would ultimately fall on rural communities, it removes some of the complexities that would be involved if local authorities attempted to recover costs directly from users. Private sector (rather than community-based) delivery of rural water services has been applied only on a small scale and in a small number of African countries, and these have not developed such taxation frameworks to date (Bernage, 2000; van Beers, 2001; Harvey *et al.*, 2003).

Costing long-term rehabilitation and expansion

Any water system has a finite lifespan and will eventually require rehabilitation. In addition, the pressures of population growth on demand for services, and desired service levels among rural communities may change over time. When determining service delivery costs these aspects should also be considered. The cost of long-term rehabilitation does not refer to the replacement of equipment or components (as covered by O&M) but to larger scale measures, such as upgrade of systems. For the example of a hand pump-equipped borehole, eventually the borehole itself may need rehabilitation owing to problems such as siltation, insufficient yield and corrosion of screens or casing. Such measures may entail considerable cost and this must be met by the supporting institution and/or the users of the system.

Currently, most rehabilitation, upgrade and expansion costs are met by the supporting institution, whether government or NGO. Many government policies and strategies do not recognize the need for rehabilitation or, if they do, accept that they will have to finance this. For example, the five-year Rural Water and Sanitation Operation Plan in Uganda states that "Government will support major rehabilitation expenses in the interim, in the long-term it is expected that communities will also take over these expenses". (DWD, 2002). While this is a long-term strategic "expectation", it is a gross overestimation to assume that communities will be able and willing to finance major rehabilitation costs where they often fail to finance the simplest repairs. It is most likely that this will only be achieved, in Uganda and elsewhere, by adopting an incremental process where costs are clear from the beginning. If communities of users are to be expected to finance rehabilitation, even in the "long term", appropriate financing mechanisms must be established in advance. Using the method described above, the "rehabilitation annuity" needs to be estimated in addition to that for replacement. This can be done using the same equation and the current cost of the rehabilitation measure that will eventually be required.

$$\text{Rehabilitation annuity, } A_R = \frac{\text{Current rehabilitation cost}}{\text{Annuity factor } (AF_{r,n})} \tag{5}$$

The "rehabilitation annuity" can then be combined with the recurrent maintenance costs and replacement annuity to calculate the household contribution needed to finance recurrent O&M, medium-term replacement and long-term rehabilitation. This is demonstrated in the following equation:

$$\text{Annual household tariff, } H = 1.2\left[\frac{M + A + A_R}{N}\right] \tag{6}$$

Box 2 uses the previous example of the India Mark II hand pump to illustrate the impact of incorporating rehabilitation costs in household water tariffs. By incorporating the need for borehole rehabilitation in twenty years' time, the monthly household tariff increases by almost two-and-a-half times from the previous value of US$0.30. This may not seem a large amount but has a significant impact on planning and may affect the users' willingness to pay for the service.

The biggest problem with this method is the difficulty in estimating future rehabilitation needs and when that rehabilitation will be required. There is always an element of unpredictability about any system and what the users may demand in the future. For example, in future it may be that a borehole becomes contaminated or damaged and is beyond rehabilitation, meaning a new one must be drilled, or that a community decides it wants a newly available technology. In such situations, adequately financing rehabilitation from the outset is almost impossible. The best option may be to work in a degree of flexibility in tariff setting which allows for some funds to be put aside to contribute to future rehabilitation costs. It remains likely, however, that the majority of these costs will continue to be met by

Box 2 Example of household tariff setting to cover rehabilitation costs

Using the earlier example for the India Mark II hand pump:

Current rehabilitation cost, R = US$1000 (for airlift and hydrofracturing)

$r = 20\%$ $n = 20$ years $N = 50$ households

$A_R = R/AF_{r,n} = 1000/4.67$ = US$214

$H = 1.2\left[\frac{M+A+A_R}{N}\right] = 1.2\left[\frac{35+119+214}{50}\right]$ = US$8.83

This can then be divided by 12 to convert to a monthly household tariff of US$0.74.

governments or external support for the foreseeable future. A water tax which consolidates taxation funds for upgrading and rehabilitation may be one way in which appropriate finances can be generated.

Tariff hierarchy development

Once the different categories of costs related to service sustainability have been determined, a tariff hierarchy can be developed which indicates the different tariffs that would need to be charged for different levels of cost recovery. Table 4 presents an example for the hand pump-equipped borehole whereby four levels of monthly household tariff are indicated. More complex water supply systems which rely on consumable energy sources such as electricity and diesel would obviously result in higher tariffs, especially for direct O&M costs. This approach can be used as a planning tool when conducting willingness to pay studies with communities and determining what costs can be met by users and what costs need to be met from alternative sources.

The last row in Table 4 is included to facilitate comparison with full cost recovery for the initial construction and associated costs (based on the same interest rate of 20% and repayment spread over ten years). This amount would need to be added to each of the above hierarchy levels if construction costs were also to be met from tariffs. As can be seen, this is a significant amount, even for a relatively low-cost technology, and is highly unlikely to be affordable by user communities.

Community financing strategies

The importance of an initial contribution to capital costs by the community remains open to debate. Indeed, some studies have shown that a higher demand for a water supply service as expressed through initial payments in cash and/or kind is actually negatively related to sustaining the service (IRC, 2002). This may be because a small percentage contribution leads to high cost solutions which are expensive to sustain. The ability of a community (or its sponsors) to make an initial contribution to project inputs does not necessarily reflect an ability, or willingness, to pay for service delivery costs over time. There is also the danger that once communities have "paid" for their facility they consider that they have already fulfilled their responsibility.

Despite growing acceptance that full cost recovery from rural water users is an unrealistic goal, there is no doubt that community financing of operation and maintenance remains a crucial issue in the quest for sustainable rural water services. The assumption that poor people have no resources at all inevitably

Table 4. Tariff hierarchy example[a].

Level of cost recovery	Estimated monthly household tariff (US$)
O&M (direct costs only)	0.30
O&M (direct costs and indirect costs)	0.63
O&M (direct costs) + rehabilitation/expansion	0.74
O&M (direct and indirect costs) + rehabilitation/expansion	1.07
Recovery of initial construction costs[b]	+4.23

[a] Example for India Mark II hand pump for a community of 300 people in Ghana.
[b] Based on cost of US$10,000 for borehole, hand pump and all associated start-up costs paid over 10 years.

leads to unsustainable subsidies and is usually inaccurate since many people are already paying a high price for sub-standard services (Evans, 1992). Indeed, the poorest people in developing countries pay more on average per litre of water than their better off compatriots (Webb & Iskandarani, 2001). Most communities do have resources and hence the ability to pay (at least something) for service delivery; however, the way in which those resources are managed will influence the ability of communities to access resources when needed, and the value assigned to a water service will affect the willingness to pay for services.

There are a number of key measures that need to be fulfilled to ensure sustainable community financing:

- Ongoing costs must be calculated and this information must be packaged in a way that communities can understand in order to make informed decisions.
- People need to be convinced of the concept of paying for water through appropriate community sensitization.
- Transparent and efficient financial management systems need to be developed.
- Willingness to pay among communities needs to be sustained through ongoing institutional support and promotion of income generation.
- Incremental strategies to phase out unsustainable subsidies, and/or develop mechanisms for sustainable cross-subsidy, need to be developed.

Costing O&M is the first step to ensure that communities are aware of ongoing costs and the financial commitment required to sustain their water systems. This allows them to select the most appropriate technology and system for them. Whatever financing system is to be used, it is essential that users are aware of typical costs from the outset and that those responsible for management are assisted in setting realistic and adequate water tariffs.

Convincing people to pay for water is often not easy in communities, especially where there is a history of receiving services for free. Past activities may have reinforced the perception of poverty and dependency among communities, which retard efforts to encourage them to pay. Political interference can also be a significant barrier to sustainable community financing since politicians commonly make promises of free services to communities for political gain (Komives & Stalker Prokopy, 2000). Changing attitudes can be difficult in such situations and requires considerable time and skills.

Accountability and transparency can go a long way to convince community members to contribute to O&M costs (Tayong & Poubom, 2002). It is important that users can see where their money is going and how it is being used, if they are to be convinced to contribute and to continue contributing. This is why it is sometimes easier to raise funds for the installation of a new facility than for its maintenance. Users may be unclear about why they should pay and what their money is being used for. If the principle of paying for water can be instilled, however, this dilemma disappears.

Community financing strategies need to include appropriate mechanisms for revenue collection and storage and investment of revenue, as well as measures to sustain willingness to pay within the community.

Revenue collection

There are many different mechanisms by which maintenance funds can be collected and stored, and locally appropriate systems should be developed through consultation with communities. The most common funding systems are:

- reactive financing
- monthly tariffs and
- pay-as-you-fetch.

Reactive financing simply means that when a system fails or breaks down the community or better-off households club together to pay for repair. *Monthly tariffs* are perhaps the most widespread system whereby each household (or adult) in the community is expected to contribute a given amount each month. *Pay-as-you-fetch* systems require a caretaker to be present at the facility at all times (except when it is locked) to collect water tariffs from the community. Users pay a fixed amount per container which is filled by the caretaker.

The advanced collection of maintenance funds does not necessarily shorten the downtime of a given water system (Batchelor *et al.*, 2000), although seasonal cash flow variations may have a big impact on whether finances can be raised rapidly (van Miert & Binamungu, 2001). Where household tariffs are paid monthly and funds are stored safely, such systems can be highly successful. Revenue collection can be conducted by CBOs or private service providers, but can be a time-consuming process, particularly where non-payers need to be chased up. Traditional leaders and respected community members can play an important role in exerting pressure and deciding where exemption or subsidy is appropriate. The most common problem encountered, however, is that willingness to pay among households is difficult to sustain and this often reduces over time, often because of a lack of trust or confidence in the water management body. Pay-as-you-fetch systems are undoubtedly the most successful in terms of revenue generated but are only possible where there is a year-round cash economy.

Storage and investment of funds

Since most rural African communities live from crisis to crisis and do not have a reliable year-round cash economy one of the major challenges in developing sustainable financing strategies is the need to establish functional mechanisms for storing funds in advance of breakdown. Where transparency and accountability are in place, maintenance funds may be stored in a bank account or with a treasurer. However, rural communities are often situated a long distance from the nearest bank, bank charges commonly rapidly eat away at the investment, or currency devaluation negates the link between funds and imported parts. An alternative strategy is for the treasurer to keep these funds for when they are needed, which relies on considerable self-discipline and the trust of the rest of the community.

In agriculture-based communities, money may be more readily available following harvests than at other times of the year. It is therefore important that alternative ways of storing resources are investigated so that funds can be raised when needed. Rather than use a bank account, communities can opt to run a cooperative whereby the water funds are used to purchase livestock or to support a community farm. Communal agricultural produce can then be sold when funds are required. This has the added advantage of avoiding devaluation effects.

Rotating savings and credit associations (ROSCAs) are cooperative financing strategies which can be used to mobilize savings for very small amounts of working capital and have been practiced for centuries in many parts of the world. Some African examples of ROSCAs include *Susu* in Ghana, *Stokvel* in South Africa, *Tontine* in most of francophone West Africa, "Merry-go-round" in Kenya, and *Chilemba* in Zambia (Williamson & Donahue, 2001). ROSCAs are designed to assist members to save money and regulate their liquidity. This is achieved by creating relationships of debt between members whereby monthly contributions are allocated to each member on a rotational basis. Since the typical ROSCA member dislikes owing the other members they are driven to fulfil their commitment to the ROSCA more reliably than they would be able to independently maintain a regular habit of saving money (Aliber, 2001).

Traditional ROSCAs, such as the "Merry-go-round" scheme in Kenya, have been used to raise capital for community contributions to construction and O&M costs for rural water systems (Harvey *et al.*, 2003). Where there is a history of cooperative financing, it is often significantly easier to raise water revenue. Such schemes can also be used to build up credit worthiness with financial institutions and generate capital for investment and income generation. There is, therefore, potential for the application of ROSCAs to be expanded to meet long-term water supply rehabilitation and expansion costs. However, this will only be successful if communities are convinced that this is their responsibility rather than that of government. There is no well-documented evidence to suggest that ROSCAs have been applied in such a way to date, but this issue requires further investigation.

Privately-managed O&M

Whether systems are managed by the community or the private sector, many of the same issues surrounding community financing apply. For rural water supplies which are managed by a private contractor or individual rather than the community, users regularly pay the contractor to run and maintain the system and may be less concerned about where the money goes and what it is used for, so long as the water supply continues to operate at the desired service level. The storage of funds becomes the responsibility of the private company which removes one level of complexity at community level. This does not, however, remove problems which may occur owing to seasonal cash-flow fluctuations. Private contractors will also need to meet overheads and meet profit targets. These costs must be included in estimating total O&M costs and setting household tariffs. However, where a company is responsible for a large number of systems for many communities, the impact of these costs on each community is likely to become very small. Given the negligible application of privately managed O&M systems in rural sub-Saharan Africa to date, however, it is not possible to assess their potential impacts on community financing adequately.

Sustaining willingness to pay

Services which rely on the users to finance ongoing running costs will only be sustainable if the willingness of users to pay is sustained. Community members who are willing to finance O&M costs in the initial stages may soon become unwilling to do so. There are a variety of possible reasons for this reduced willingness to pay:

- lack of transparency and accountability relating to the water management committee,
- no faults with the facility and therefore no clear reason for paying,
- dissatisfaction with water supply (location, time to queue, water quality/quantity),
- competition from cheaper water sources and
- change in individual priorities.

Perhaps the most effective mechanism that can be used to sustain willingness to pay is appropriate institutional support for communities. Where communities are regularly visited by an overseeing institution to monitor systems this reaffirms the need to contribute to the cost of O&M. The institution can advise communities on how to make best use of unspent funds through investment, can regulate water committees to ensure transparency, and can help to rectify any causes of dissatisfaction with a particular water system. Quarterly monitoring visits provide an ideal mechanism to identify problems early and find sustainable solutions.

The second measure that can assist greatly in sustaining willingness to pay relies on a major mind shift among community members. If water supply users understand that they must pay for water, rather than to maintain a system, many of the obstacles to sustained community financing disappear. Such a mindset needs to be established early on in the community consultation process and, where there are existing facilities installed under different programmes, this is likely to be difficult to achieve. New programmes, however, have the opportunity to develop awareness and place the emphasis on "water" rather than the "facility". If users accept from the outset that they have to pay for water from an improved water supply and that this will always be the case, financing is more likely to be sustained, providing that the service supplied meets the standard demanded by the users.

Another key measure to ensure sustained financing of O&M is to use water to generate income. Where water directly leads to income generation, the problem of community financing may become significantly less since water users have increased incentive to ensure that the system keeps operating and are more likely to have finances readily available to enable O&M. Water-related income generation ventures in rural areas include livestock watering, irrigation for market gardens, block making, beer brewing and food processing. There is little documented evidence, however, of successful income generation from systems designed primarily for the supply of drinking water.

Pro-poor financing strategies

The United Nations Committee on Economic, Cultural and Social Rights issued a statement in November 2002 declaring access to water a human right and stating that water is a social and cultural good, not merely an economic commodity (World Water Council, 2002). However, the necessary financing and governance structures to guarantee access to safe, sufficient and affordable water are commonly lacking (Mehta, 2004). In order to achieve this aim it is important to find ways in which to serve the poorest and most vulnerable, while ensuring that sufficient finances are generated to sustain services. As has been mentioned, full cost recovery for operation and maintenance from rural communities in Africa, at least on a large scale, has not been achieved to date. This indicates that capital and recurrent costs are routinely subsidized by external support agencies or governments. This should not be a cause for surprise. Most urban water authorities depend on subsidies to cover part of their recurrent costs and virtually all their capital spending on expansion and modernization (Winpenny, 2003). There is, therefore, no logical reason why higher rates of cost recovery should be expected from rural water users, who are in general, poorer.

Subsidy in itself is not a threat to sustainability provided that the subsidies themselves are either transitional or sustainable. The World Panel on Financing Water Infrastructure recommends that subsidies should be "targeted, transparent and, where they are intended to ease the transition to higher tariffs, tapering" (Winpenny, 2003). Inherent within this statement is recognition of the fact that while some subsidies may act as a bridge to the generation of higher revenues, equally some subsidies may be required on an indefinite basis. What is essential is that such subsidies are affordable in the long term and are budgeted for accordingly.

Least subsidy option

One way to ensure that the poor are adequately served is to offer direct subsidies to poor communities. These are likely to be partial rather than total subsidies, and in effect this is often what happens since users rarely meet the full cost of O&M. A formalized version of this is the bidding for least subsidy approach (Figure 1). In this model private service providers bid for the minimum or least subsidy from government to provide water systems at agreed service levels for a period of say, 10 to 15 years. These private companies need to assess and negotiate the community contribution they will get for O&M. The government then pays the minimum subsidy to the company and the communities pay their water tariffs. This model has not been applied to rural water services in Africa to date but its application to other sectors, such as rural telecommunications (Cannock, 2001), demonstrates considerable potential for where services are delivered by the private sector.

Community cross subsidy

Many poor rural people are currently subsidized by other more affluent members of their community. Community management systems often recognize that some households are unable to afford water tariffs and therefore exempt them from payment (Harvey *et al.*, 2003). This is a sensitive issue since it may give rise to internal disagreement or envy and is open to abuse. It is, however, highly effective where community management is strong and allows the poorest and most vulnerable to be supported and

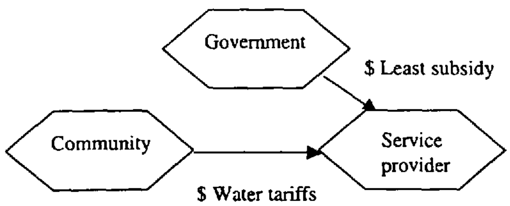


Fig. 1. Least subsidy option.

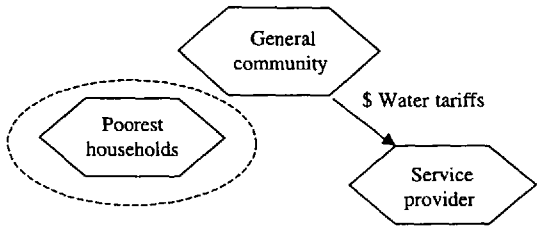


Fig. 2. Community cross subsidy.

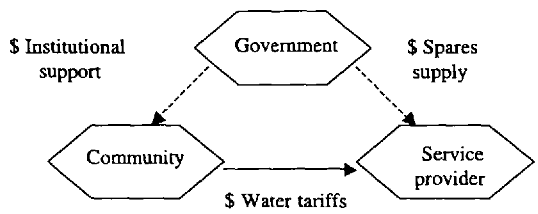


Fig. 3. Hidden subsidies (dashed).

protected by the rest of the community. The service provider in this case may be a CBO or private individual/organization (Figure 2).

This system of cross subsidy within a community is difficult to formalize and relies upon the goodwill and objectivity of the management committee. For privately managed water supplies a more formalized system is to apply individual means-tested water subsidies whereby the poorest households receive a government subsidy and pay less for water. The subsidy may be funded entirely by the government or from other users. This has been successfully implemented for urban water services delivered by the private sector (Gómez-Lobo, 2001) but has not yet been transferred to the rural sector.

Hidden subsidies

Some subsidies for operation and maintenance of rural water supplies are indirect or "hidden". These commonly include support for spare parts supply, storage and distribution, and monitoring, regulation and institutional support for communities. Here, the service provider may be a local mechanic who obtains spare parts from a local NGO or subsidized dealer (Figure 3). It may be accepted that some level of such subsidy is needed, particularly for institutional support, but where possible, attempts should be made to phase out hidden subsidies over time and these costs should be worked into long-term financial plans.

Conclusions

There is growing acceptance that full cost recovery for rural water services is an unrealistic goal, since the capital costs of water infrastructure provision remain beyond the means of most rural communities. Yet while communities are widely expected to finance recurrent operation and maintenance costs, this goal is still not being realized in many parts of sub-Saharan Africa. One of the reasons for this is an *ad hoc* approach to estimating costs and establishing tariffs. If sustainable financing strategies are to be developed, it is essential that the cost of ongoing service delivery is determined, so that communities, local authorities and implementing agencies are aware of the long-term costs involved and can plan accordingly.

One way in which this can be achieved is to develop a tariff hierarchy that provides estimates of the tariffs required for different levels of cost recovery. This can be done only by conducting a comprehensive assessment of the maintenance, repair and rehabilitation needs for different water system technologies and costing these. The vast majority of implementing agencies do not do this and consequently it is unclear what selected tariffs can be expected to cover and what additional financing may be required. Unless this situation changes, rural water systems are likely to continue rapidly to fall into disrepair and the need for rehabilitation projects is likely to continue *ad infinitum*.

The research in Ghana indicated that direct O&M costs are generally affordable for rural communities but that there is a need to take action to sustain willingness to pay and to develop appropriate community financing strategies which are matched to the specific characteristics of communities. These strategies must consider both how water revenue is collected and also how it is stored or invested.

The costs of institutional support from local government authorities (or substitute agencies) need to be met by public financing and must be budgeted for accordingly. If private sector service delivery becomes more widespread, it is possible that this can be met from tax revenue raised from end users, but this remains a far-off goal at present. The costs of rehabilitation and expansion of water systems can, in theory, be met by user communities but this raises tariffs significantly and is largely dependent on community acceptance of the need to pay for water. This also makes the need for appropriate investment of water revenue even more crucial and new approaches need to be investigated.

There is a need for realism from all stakeholders to identify what costs can be met by water users and what costs need to be met by national or external support. Just as the vast majority of urban water services require some form of subsidy, so do rural water services. This issue cannot be avoided by pretending that the goal of cost recovery for ongoing running costs is currently realistic. There is a need for policy makers and strategic planners in international development agencies and national governments to face up to this issue. They will only do so if sector professionals are prepared to calculate the real costs involved in service delivery and to develop and advocate realistic financing strategies, which will almost certainly need to include targeted and transparent subsidies, at least for the foreseeable future.

Acknowledgements

The initial research for this paper was conducted as part of a Knowledge and Research (KaR) project "Guidelines for Sustainable Hand pump Projects in Africa" (R7817), funded by the Department for International Development (DFID) of the British Government, and conducted by the Water, Engineering and Development Centre (WEDC), Loughborough University. Opinions noted within this paper do not necessarily represent those of DFID or the project team but are solely those of the author.

References

Aliber, M. (2001). Rotating savings and credit associations and the pursuit of self-discipline. In *African Review of Money Finance and Banking, 2001*. "Giordano dell'Amore" Foundation, Milan, 1 p.

Annan, K. A. (2000). *"We the Peoples" The role of the United Nations in the 21st Century*, United Nations, New York.

Batchelor, S., McKemey, K. & Scott, N. (2000). *Exit Strategies for Resettlement of Drought Prone Populations (Project Technical Report)*. Gamos Ltd, Reading.

Baumann, E. (2005). *Common RWSN Context*. Discussion Paper. SKAT, St. Gallen, Switzerland.

Bernage, F. (2000). Local private sector involvement: the Mauritania experience. Paper presented at *SKAT/HTN Workshop on Civil Society and Government Partnerships in RWS*. Hyderabad, India, March 2000. SKAT, Switzerland.

Cannock, G. (2001). Expanding rural telephony: output-based contracts for pay phones in Peru. In *Contracting for Public Services: Output-based aid and its applications*. Brook, P. J. & Smith, S. M. (eds). The World Bank, Washington DC.

Carter, R. C., Tyrrel, S. F. & Howsam, P. (1999). Impact and sustainability of community water supply and sanitation programmes in developing countries. *Journal of the Chartered Institute of Water and Environmental Management, 13*, 292–296.

Deverill, P., Bibby, S., Wedgwood, A. & Smout, I. (2002). *Designing Water Supply and Sanitation Projects to Meet Demand in Rural and Peri-Urban Communities: Book 1. Concept, principles and practice*. WEDC, Loughborough University.

DWD (2002). *Rural Water and Sanitation Operation Plan: 20022007*. Version 1, September 2002, Directorate of Water Development, Ministry of Water. Lands and Environment, The Republic of Uganda.

Evans, P. (1992). *Paying the Piper: an overview of community financing of water and sanitation*. IRC, Delft, The Netherlands.

Fonseca, C. (2003). Cost recovery: taking into account the poorest and systems sustainability. In *International Congress Proceedings of the International Congress Watershed Management for Water Supply Systems* 29 June–3 July 2003. American Water Resources Association, New York, p. 1.

Fonseca, C. & Cardone, R. (2004). *Analysis of Cost Estimates and Funding Available for Achieving the Millennium Development Goals Targets for Water and Sanitation*. WELL Project 1.3, WELL, Loughborough University.

Fonseca, C. & Njiru, C. (2003). Financing and cost recovery: what happens after construction? *Proceedings of 29th WEDC Conference, Abuja, Nigeria, 2003*. Harvey, P. A. (ed). WEDC, Loughborough University, pp. 242–244.

Gómez-Lobo, A. (2001). Making water affordable: output-based consumption subsidies in Chile. In *Contracting for Public Services: Output-based Aid and its Applications*. Brook, P. J. & Smith, S. M. (eds). The World Bank, Washington DC, pp. 23–30.

Harvey, P. A. & Reed, R. A. (2004). *Rural Water Supply in Africa: Building blocks for sustainability*. WEDC, Loughborough University.

Harvey, P. A., Ikumi, P. N. & Mutethia, D. K. (2003). *Sustainable Handpump Projects in Africa: Report on Fieldwork in Kenya*. WEDC, Loughborough University.

IRC (2002). *Participatory Learning and Action Initiative*. IRC, Delft, The Netherlands.

Komives, K. & Stalker Prokopy, L. (2000). *Cost Recovery in Partnership: Results, attitudes, lessons and strategies*. BPD Water and Sanitation Cluster, London.

Lane, J. (2004). *Rural Water Supply and Sanitation in Africa*. presented at the Global Learning Process on Scaling up Poverty Reduction Shanghai Conference, May 25–27, 2004. Water and Sanitation Program, World Bank.

MacDonald, D. A. & Pape, J. (2002). *Cost Recovery and the Crisis of Service Delivery in South Africa*. Human Science Research Council, Cape Town, South Africa.

Mehta, L. (2004). *Financing Water for All: Behind the border policy convergence in water management*. IDS Working Paper 233. IDS, Sussex University.

Nedjoh, J., Thogersen, J. & Kjellerup, B. (2003). Challenges of O&M in the sustainability of rural water facilities. In *Proceedings of 29th WEDC Conference, Abuja, Nigeria, 2003*. Harvey, P. A. (ed). WEDC, Loughborough University, pp. 126–129.

RWSN (2005). *RWSN Strategy Paper: Sustainable Handpumps*. SKAT, St. Gallen, Switzerland.

Schouten, T. & Moriarty, P. (2003). *Community Water, Community Management – From system to service in rural areas*. ITDG Publishing/IRC, London.

Tayong, A. & Poubom, C. (2002). *Convincing People to Pay for Water: Nkouondja in Cameroon*. IRC, Delft, The Netherlands.

van Beers, P. (2001). Leasing, a new handpump O&M concept. In *Proceedings of 27th WEDC Conference, Lusaka, Zambia, August 2001*. Scott, R. (ed). WEDC, Loughborough University, pp. 413–415.

van Miert, T. & Binamungu, D. (2001). *The Shinyanga Experience: Water user group concept as a sustainable management system for hand pump wells*. SKAT, St. Gallen, Switzerland.

Webb, P. & Iskandarani, M. (2001). *The poor pay much more for water and use much less*. Water and Sanitation Update, Netwas, Nairobi.

Wedgwood, A. & Sansom, K. (2003). *Willingness-to-pay Surveys – A Streamlined Approach: Guidance notes for small town water services*. WEDC, Loughborough University.

WHO (2000). *Tools for Assessing the O&M Status of Water Supply and Sanitation in Developing Countries*. World Health Organization, Geneva.

WHO/UNICEF (2004). *Meeting the MDG Drinking Water and Sanitation Target: A mid-term assessment of progress*. World Health Organization, Geneva.

Williamson, J. & Donahue, J. (2001). *A Review of the COPE Program and its Strengthening of AIDS Committee Structures*. Displaced Children and Orphans Fund, USAID, Washington DC.

Winpenny, J. (2003). *Financing Water for All*. Report of the World Panel on Financing Water Infrastructure. World Water Council/Global Water Partnership.

World Water Council (2002). *UN Consecrates Water as Public Good, Human Right*. World Water Council, www. worldwatercouncil.org/download/ UN_water_public_good.pdf.

World Water Council (2004). *Analysis of the 3rd World Water Forum*. World Water Forum, Secretariat of the Third World Water Forum.

Water Policy 9 (2007) 373–391

Cost determination and sustainable financing for rural water services in sub-Saharan Africa

Peter A. Harvey

er, Engineering and Development Centre (WEDC), Institute of Development Engineering, Loughborough University, Loughborough, LE11 3TU, UK. Tel: 01509-228743, Fax: 01509-211079. E-mail: P.A.Harvey@lboro.ac.uk

Received 19 December 2005; accepted in revised form 29 March 2006

ract

cess to safe, sufficient and affordable water in rural Africa will not increase unless sustainable financing gies are developed which ensure the sustainability of existing water services. There is a strong need for ıational donors and national governments to confront the true costs associated with sustained service sion in order to develop practicable long-term financing mechanisms. This paper presents a systematic ɪach that can be applied to determine the overall cost of service delivery based on respective cost estimates for ıtion and maintenance, institutional support, and rehabilitation and expansion. This can then be used to lop a tariff hierarchy which clearly indicates the cost to water users of different levels of cost recovery, and h can be used as a planning tool for implementing agencies. Community financing mechanisms to ensure ined payment of tariffs must be matched to specific communities and their economic characteristics; a blanket ɪach is unlikely to function effectively. Innovative strategies are also needed to ensure that the rural poor are uately served, for which a realistic, targeted and transparent approach to subsidy is required.

Keywords: Africa; Developing countries; Financing; Rural water supply; Sustainability

oduction

the year 2000, the United Nations, through the Millennium Development Goal (MDG) for ronmental sustainability, set the international target to halve the proportion of people without ıinable access to safe drinking water by the year 2015 (Annan, 2000). Estimates of the annual stment required to finance this target vary enormously, but the majority are almost certainly ːrestimates since they do not account for maintenance and rehabilitation of existing infrastructure, consider the costs of maintaining the institutions and support services required for service ıinability (Fonseca & Cardone, 2004).

0.2166/wp.2007.012

Rural sub-Saharan Africa has the lowest water service coverage of any region in the world at 45% in the ›ar 2002; if current trends continue the MDG target will not be met, primarily because of conflict and ›litical instability, high population growth rates and low priority given to water and sanitation VHO/UNICEF, 2004). This major challenge is exacerbated by limited sustainability of existing rural water ›stems, with an estimated 35% of systems in sub-Saharan Africa being out of operation at any given time 3aumann, 2005). Before ambitious coverage targets can be considered, it is essential that both existing and ›w rural water services are sustained. One of the main reasons for poor levels of sustainability is the ›evalence of unacceptable, unaffordable or impracticable financing strategies (Carter *et al.*, 1999). The ›velopment of sustainable financing mechanisms is therefore imperative to ensure sustainable service rovision. This cannot be achieved unless realistic long-term costs are determined. There has been far too ttle attention given to this issue by donors, governments and implementing agencies in the past, and ›nsequently few countries have realistic policies, operational strategies or plans for sustainable financing ›r increased service coverage, particularly for the poor (Fonseca, 2003).

The current situation has arisen primarily owing to the policies and practices of international donors nd western development agencies. The development project approach adopted has provided a onvenient concept to abrogate responsibility for long-term service provision from implementing gencies, be they non-governmental organizations (NGOs), bilateral agencies or governmental uthorities, to poor rural communities. The presumption that once a new water supply is constructed and handed over" to the user community it can be sustained by community financing of operation and ›aintenance (O&M) is over-simplistic, especially since the long-term O&M costs are neither calculated or communicated to water users. This simplistic approach is reflected in the western-influenced policies nd strategies of many African countries. A brief analysis of the 20 sub-Saharan African countries with ompleted poverty reduction strategy papers (PRSPs) reveals that 85% of those countries have an mphasis on community management and financing of rural water supplies in key national strategy ocuments, yet these do not adequately address the determination, nor affordability, of associated costs. f this does not change then sustainability levels will remain unacceptably low and the proportion of ›eople without access to safe drinking water in rural Africa will remain unacceptably high.

This paper, based on research on sustainability of rural water services in sub-Saharan Africa, with a ›articular focus on Ghana, presents a systematic approach that can be used to estimate the true cost of ustainable service delivery to the consumer. It also identifies potential financing mechanisms which nsure service sustainability for the rural poor.

›ost recovery

The term "cost recovery" is routinely referred to in rural water projects and programmes but can be pplied in many different ways. In general, cost recovery refers to the practice of charging users the full (or ›early full) cost of providing services (MacDonald & Pape, 2002). Full cost recovery means eimbursement to service providers of both recurring and non-recurring costs associated with onstruction, management, O&M, rehabilitation and expansion of water systems. Costs include, but are ›ot limited to, the costs of community mobilization, planning, design, administration, construction and ›&M. Full cost recovery for rural water services in Africa is rarely, and probably never, achieved because:

the cost of systems is significantly beyond the means of most rural communities; and political and humanitarian desire for improved access to water, and definition of water as a "right", an implementers are reluctant to seek full reimbursement.

hereas during the Second World Water Forum in 2000 full cost recovery was advocated, during the l Word Water Forum in 2003 the concept of sustainable cost recovery emerged, in which the general ssity for subsidies, especially for the poor, was acknowledged (World Water Council, 2004). Whilst it is ally agreed and widely accepted within the donor community that users should pay for operation and tenance costs, there is no consensus on whether users should pay for capital costs and if so, what ntage is reasonable and how might it be paid (Fonseca & Njiru, 2003). Cost recovery for construction nstallation of new rural water systems and facilities is, in practice, negligible. Communities are often ested to contribute 5 to 15% of initial capital costs, which usually means the cost of the water facility (e.g. a hand pump installed on a borehole). The costs of mobilization, administration, management and portation generally remain hidden. Even where communities are expected to make a financial ibution, this is commonly intended to demonstrate demand, instil a sense of ownership and act as an ator of the community's ability to organize and collect payments, rather than a real attempt to recover l implementation costs (Deverill *et al.*, 2002). It is generally accepted that user financing of full ementation costs for improved rural water systems is an unrealistic goal. In a rural African context, fore, the infrastructure development required to ensure increased access to water is likely to remain ndent on external donor support or continuous national government investment (Lane, 2004).

st recovery for ongoing service delivery and recurrent O&M costs may be a more achievable target, but nce suggests that the majority of community organisations and small service providers are failing to rate sufficient revenues even to meet the direct O&M costs of existing systems (Fonseca, 2003). Direct 1 costs comprise those for maintenance, repair and asset replacement. Even where cost recovery for O&M atively high this rarely reaches 100%, owing to hidden costs such as subsidy of spare parts provision, ly chains and institutional support from local government or aid agencies (Harvey & Reed, 2004).

eally, the water tariffs that users pay should cater for future system upgrade, rehabilitation and nsion costs, as well as ongoing O&M costs. Currently, this occurs very rarely, if ever. One of the constraints is the need for a transparent, secure and sustainable method of storing and investing ey for future use. Community-managed financing mechanisms are rarely able to fulfil these irements. Private sector service providers could potentially do this but require sufficient incentive regulation. The second key constraint is insufficient ability and willingness to pay for these costs ng users. In many cases it may be unrealistic to expect poor rural communities to finance these costs this highlights the need for an external institution (ideally local government) to provide appropriate ort. This also applies to emergency needs, such as the results of sabotage or natural disasters.

e term cost recovery as applied to rural water services remains generally misleading, since capital costs imply not recovered, and even where direct O&M costs are met by users, revenues are generally ficient to recover indirect costs such as the cost of developing adequate institutional capacity to provide ort. The term "sustainable financing" is therefore used in this paper since this better articulates the need ay for water", i.e. finance the cost of ongoing provision of a water service on an indefinite basis.

determination

etermination of the real costs of service provision is one of the key problems in developing inable financing strategies (Fonseca & Njiru, 2003). Most implementing agencies simply do not ddress this issue adequately, in part because there is a lack of systematic guidelines to estimate costs. Vithout comprehensive cost determination, however, it is impossible to inform water users of the true ost of service sustainability to them, or to determine the level of external financial support that may be equired. If sustainable financing mechanisms are to be developed, so that rural water services are to be ustainable, the following three categories of cost must first be calculated:

direct O&M costs;
indirect O&M costs (institutional support costs) and
rehabilitation and expansion costs.

Costing operation and maintenance

The main consideration when determining direct O&M costs for rural water systems is to ncorporate recurrent repair costs and future asset replacement costs. Without considering the need or saving specific sums of money to replace major component parts, the sustainability of most vater systems is undermined. One method that can be used to do this is *amortization* whereby qual amounts are set aside every year, taking into account interest rates. These amounts can form art of the O&M tariffs charged. A four-stage process that can be used to determine appropriate ariffs is outlined below. The India Mark II hand pump is used as an example to illustrate the rocess. This was selected since hand pumps remain the principal technology for improved rural vater supplies in sub-Saharan Africa (RWSN, 2005) and the India Mark II is one of the most ommon public domain hand pumps, which has been adopted as a "standardized" pump in several African countries, including Ghana. It is accepted that there are many other rural water echnologies in addition to the conventional hand pump, and the process developed, as presented ere, can also be applied to them.

1. *Recurrent O&M costs*: the first step is to calculate recurrent O&M costs, which include replacement of minor components and routine preventive maintenance, and any wages associated with these. Table 1 gives an example of components, costs and estimated frequency of replacement for an India Mark II hand pump. The total annual cost of components, C can be determined by dividing each unit cost by the estimated frequency of replacement and summing these.

The annual cost of components may vary considerably, even for the same technology, and depends on he local environment. For example, hand pumps operating in areas of deep, aggressive (low pH) groundwater which are subjected to heavy usage, may have much higher O&M costs than those operating in shallow, neutral conditions with low usage. The only reliable way to obtain guidance for costs in specific local conditions is through appropriate monitoring.

Once the total annual cost of components, C, is determined the annual maintenance cost, M, can be letermined by adding the required labour and transportation cost, L. This will vary depending on the ocal economy and type of maintenance system utilised.

$$\text{Annual maintenance cost, } M = \text{Annual cost of components, } C + \text{Labour/transport costs, } L \quad (1)$$

1. Example of recurrent O&M component costs for an India Mark II hand pump[a].

onent	Estimated frequency of replacement, f (year)	Unit cost, U (US$)	Annual cost, U/f (US$)
; seal	2	1.60	0.80
ather	2	1.00	0.50
	3	3.60	1.20
e axle	3	6.00	2.00
earing	3	7.50	2.50
10 nut	1	1.50	1.50
50 nut	1	1.50	1.50
alve rubber	3	6.00	2.00
valve rubber	2	1.00	0.50
e	1	2.50	2.50
annual cost of components, C =			20.00

d on data from Ghana. This is an example only; f and U will depend on local economy, quality and age of equipment, nmental conditions and usage pressure.

g the example in Table 1 and average figures obtained in Ghana, assuming the area pump mechanic to make an average of two visits per year and charges US$5.00 per visit, plus US$2.50 for portation, the total annual cost of labour and transportation is US$15.00. Therefore:

$$\text{ual maintenance cost, } M = C + L = 20.00 + 15.00 = \text{US\$}35.00 \tag{2}$$

e the costs are relatively low and are set in hard currency, any inflationary increases are not idered since these are likely to be negligible.

Current replacement costs: the second step is to calculate the current replacement costs and the cted lifespan of major components which are likely to need to be replaced. Depending on the nology and environment this may be based on the replacement of the entire facility (e.g. hand pump) ecific components of that facility. Table 2 gives an example of the major components of an India k II hand pump which may need replacing after a five-year period of use, and their respective costs. nce calculated, the estimated replacement cost should be compared to the total current cost of a plete facility. For example, in some cases the cost of a complete hand pump may be lower than or lar to that of the component parts, particularly where pumps are ordered in bulk. If this is the case the e hand pump could be replaced after five years rather than the major components listed.

he current replacement cost, R is the current cost of complete facility or major components and n is stimated number of years before replacement. The value of n may be greater than 5 and will depend he particular technology, model, manufacturer and conditions under which it is operating.

Annuity: the next step is to calculate the annual amount or *annuity* which needs to be put aside each to meet future replacement costs. This is based on an annuity factor (AF), which is a function of the cted lifespan of the equipment in years (n) and the interest rate (r) in the local economy (Wedgwood ansom, 2003). This does not consider inflation but allows for devaluation, which is especially ortant for imported components and overrides inflation effects in many developing countries. The wing equation can be used:

$$\text{uity, } A = \frac{\text{Current replacement cost, } R}{\text{Annuity factor } (AF_{r,n})} \tag{3}$$

able 2. Example of 5-year replacement costs for an India Mark II hand pump[a].

omponent	Unit cost (US$)
land pump cylinder	115.00
oot valve	8.00
land pump tank	22.00
land pump head	81.00
0 Connecting rods	80.00
pron and drainage repairs	30.00
otal replacement cost, $R =$	336.00

This is an example based on data from Ghana, which identifies components requiring replacement five years after installation, ssuming that stainless steel riser pipes are used. Where galvanised iron pipes are used which are likely to be subject to orrosion, these should be included in the cost estimate.

Annuity factors are based on number of years and interest rates and can be read directly off financial cost ables. In order to adjust for inflation the annuity can be multiplied by the cumulative inflation rate.

4. *Average annual cost of O&M*: the final step is to calculate the average annual cost of O&M per iousehold. Ideally, the annual amount paid each year (or saved in a communal/private fund) should be slightly higher than the calculated annuity to allow for unforeseen events and inflation. A contingency factor of 20% can be used to compensate for this and will ensure that the users have saved enough to compensate for future price changes for the required component. The household tariff per year, H, can be estimated using equation (4), where N is the number of households in the community:

$$\text{Annual household tariff, } H = 1.2\left[\frac{M + A}{N}\right] \tag{4}$$

This is based simply on the total number of households using the facility. To ensure equity, household tariffs can be modified by three factors: the distance from the source, the number of people in the household and "special" factors such as poverty or disability (Deverill *et al.*, 2002). Box 1 gives a worked example for a hand pump water supply.

The household tariffs calculated for low-cost community water systems, such as hand pumps and gravity-fed systems, are generally very low and normally below US$0.50 a month (Harvey & Reed, 2004). The process above can be repeated after five years to assess whether an increase in tariff is required based on the costs at that time. Alternatively, tariffs may be calculated for a twenty-year period from the start of the service, accounting for repeated replacement of major components and/or pumps. Ongoing monitoring and regulation is essential to make appropriate adjustments for changing circumstances. The above process does not include costing for rehabilitation and expansion.

Costing institutional support

The assumption that supporting community-based O&M is a less onerous task than running a centralized maintenance system has not been borne out in the field (WHO, 2000). In recent years there has been a growing awareness and acceptance of the need to provide institutional support for

1 Example of household tariff setting for a hand pump water supply
Jsing the example for the India Mark II hand pump above:
ıl annual maintenance cost, $M = \$35$
rent replacement cost, $R = \$336$
mated number of years before replacement, $n = 5$ years
ıroximate interest rate, $r = 20\%$
ıuity factor (read from table) $AF_{r,n} = 2.83$
ıuity, $A = R/AF_{r,n} = 336/2.83 = \text{US\$119}$
nber of households, $N = 50$ (300 people)
ıual household tariff, $H = 1.2\left[\frac{M+A}{N}\right] = 1.2\left[\frac{35+119}{50}\right] = \text{US\$3.70}$
s can then be divided by 12 to convert to a monthly household tariff of US$0.30.

nunity-based management systems (Schouten & Moriarty, 2003). Appropriate institutional support ɔrises the following components:

couragement and motivation
ɔnitoring and evaluation
rticipatory planning and regulation
pacity building and
ecialist technical assistance (including financial support where required).

ıch support obviously has an ongoing cost associated with it and although this has been largely red in the past, some governments are now attempting to address this. Nedjoh *et al.* (2003) cite the of the Volta Region of Ghana where local government institutions earmark 6% of investment funds crease access to rural water supply for monitoring and O&M of all new and existing systems. This is d on an ongoing programme to construct 100 new water points per annum, in an area with 500 .ing water points. Obviously, institutional costs will vary considerably from location to location and ıy be that a direct relationship with expansion investment is not always appropriate. It is essential, ever, that the cost of institutional support is estimated and that appropriate budgetary allocation is e for this. Table 3 presents an example breakdown of costs for institutional support which shows the cts which should be considered and estimated cost ratios for these. These costs are based on ıultation with government agencies and NGOs in Ghana and are indicative only.

he above costing example equates to US$100 per supported community per year. Such a cost should ɔe excessive to a local government authority and for 100 communities is roughly the cost of one hand .p-equipped borehole in many African countries. The figure quoted could be reduced considerably ıer where institutions support a greater number of communities, where communities develop ɜased self-sufficiency, or where support from other stakeholders (e.g. non-profit organizations) is lable. What is vitally important is that institutions attempt to estimate costs and budget accordingly. ɹpport costs need to be determined locally and appropriate long-term funding mechanisms sought. If cost recovery were to be realised from users, communities would also be expected to meet the cost ıstitutional support. Using the example of the hand pump water supply in Ghana, this would result in iff increase of 100% for an average community of 300 people. It would also mean that they would be ired to pay this increase in taxation to local authorities, which would require the establishment of able 3. Example breakdown of costs for institutional support.

.ctivity	Annual cost per 100 communities (US$)
1onitoring and evaluation:	3,000
uarterly monitoring visits to all communities	
'articipatory planning and regulation:	2,000
aison with problem communities and CBOs to develop solutions	
,pecialist technical assistance:	2,000
dvice and intervention for unforeseen technical problems	
'apacity building:	3,000
raining of stakeholders (staff, communities, private sector etc.)	
'otal annual cost per 100 communities =	10,000

:ommunity-based organisations (CBOs) as legal entities and an effective regulatory framework. This 'emains a far-off goal at present and it is difficult to envisage CBOs ever agreeing to pay local government a proportion of the revenue raised from water users, particularly as there is often a raditional expectation that government should provide water services free-of-charge. The reality is that ocal government institutions need to develop budgets which recognize the need for such expenditure on ı long-term basis.

Even where water supply management systems are not community based, institutional support costs ıre likely to remain at similar levels. In public-private models community-based support costs would be :eplaced with those related to regulation of the private sector. The added advantage of this model is that :axation of the private sector has the potential to contribute to funding this support. Although the cost of :his would ultimately fall on rural communities, it removes some of the complexities that would be ınvolved if local authorities attempted to recover costs directly from users. Private sector (rather than :ommunity-based) delivery of rural water services has been applied only on a small scale and in a small number of African countries, and these have not developed such taxation frameworks to date (Bernage, 2000; van Beers, 2001; Harvey *et al.*, 2003).

Costing long-term rehabilitation and expansion

Any water system has a finite lifespan and will eventually require rehabilitation. In addition, the pressures of population growth on demand for services, and desired service levels among rural communities may change over time. When determining service delivery costs these aspects should also be considered. The cost of long-term rehabilitation does not refer to the replacement of equipment or components (as covered by O&M) but to larger scale measures, such as upgrade of systems. For the example of a hand pump-equipped borehole, eventually the borehole itself may need rehabilitation owing to problems such as siltation, insufficient yield and corrosion of screens or casing. Such measures may entail considerable cost and this must be met by the supporting institution and/or the users of the system.

Currently, most rehabilitation, upgrade and expansion costs are met by the supporting institution, whether government or NGO. Many government policies and strategies do not recognize the need for rehabilitation or, if they do, accept that they will have to finance this. For example, the five-year Rural Water and Sanitation Operation Plan in Uganda states that "Government will support major ilitation expenses in the interim, in the long-term it is expected that communities will also take over expenses". (DWD, 2002). While this is a long-term strategic "expectation", it is a gross stimation to assume that communities will be able and willing to finance major rehabilitation costs : they often fail to finance the simplest repairs. It is most likely that this will only be achieved, in da and elsewhere, by adopting an incremental process where costs are clear from the beginning. If unities of users are to be expected to finance rehabilitation, even in the "long term", appropriate cing mechanisms must be established in advance. Using the method described above, the bilitation annuity" needs to be estimated in addition to that for replacement. This can be done using ame equation and the current cost of the rehabilitation measure that will eventually be required.

$$\text{bilitation annuity, } A_R = \frac{\text{Current rehabilitation cost}}{\text{Annuity factor } (AF_{r,n})} \tag{5}$$

"rehabilitation annuity" can then be combined with the recurrent maintenance costs and cement annuity to calculate the household contribution needed to finance recurrent O&M, medium-replacement and long-term rehabilitation. This is demonstrated in the following equation:

$$\text{al household tariff. } H = 1.2\left[\frac{M + A + A_R}{N}\right] \tag{6}$$

2 uses the previous example of the India Mark II hand pump to illustrate the impact of incorporating bilitation costs in household water tariffs. By incorporating the need for borehole rehabilitation in ty years' time, the monthly household tariff increases by almost two-and-a-half times from the ious value of US$0.30. This may not seem a large amount but has a significant impact on planning may affect the users' willingness to pay for the service.

e biggest problem with this method is the difficulty in estimating future rehabilitation needs and n that rehabilitation will be required. There is always an element of unpredictability about any m and what the users may demand in the future. For example, in future it may be that a borehole mes contaminated or damaged and is beyond rehabilitation, meaning a new one must be drilled, or a community decides it wants a newly available technology. In such situations, adequately financing bilitation from the outset is almost impossible. The best option may be to work in a degree of bility in tariff setting which allows for some funds to be put aside to contribute to future bilitation costs. It remains likely, however, that the majority of these costs will continue to be met by

x 2 Example of household tariff setting to cover rehabilitation costs

Using the earlier example for the India Mark II hand pump:

rrent rehabilitation cost, R = US$1000 (for airlift and hydrofracturing)

= 20% $n = 20$ years $N = 50$ households

$= R/AF_{r,n} = 1000/4.67 =$ US$214

$= 1.2\left[\frac{M+A+A_R}{N}\right] = 1.2\left[\frac{35+119+214}{50}\right] =$ US$8.83

is can then be divided by 12 to convert to a monthly household tariff of US$0.74.

›vernments or external support for the foreseeable future. A water tax which consolidates taxation ınds for upgrading and rehabilitation may be one way in which appropriate finances can be generated.

ariff hierarchy development

Once the different categories of costs related to service sustainability have been determined, a tariff ierarchy can be developed which indicates the different tariffs that would need to be charged for ifferent levels of cost recovery. Table 4 presents an example for the hand pump-equipped borehole /hereby four levels of monthly household tariff are indicated. More complex water supply systems /hich rely on consumable energy sources such as electricity and diesel would obviously result in higher ariffs, especially for direct O&M costs. This approach can be used as a planning tool when conducting villingness to pay studies with communities and determining what costs can be met by users and what osts need to be met from alternative sources.

The last row in Table 4 is included to facilitate comparison with full cost recovery for the initial :onstruction and associated costs (based on the same interest rate of 20% and repayment spread over ten 'ears). This amount would need to be added to each of the above hierarchy levels if construction costs vere also to be met from tariffs. As can be seen, this is a significant amount, even for a relatively low-:ost technology, and is highly unlikely to be affordable by user communities.

Community financing strategies

The importance of an initial contribution to capital costs by the community remains open to debate. Indeed, some studies have shown that a higher demand for a water supply service as expressed through initial payments in cash and/or kind is actually negatively related to sustaining the service (IRC, 2002). This may be because a small percentage contribution leads to high cost solutions which are expensive to sustain. The ability of a community (or its sponsors) to make an initial contribution to project inputs does not necessarily reflect an ability, or willingness, to pay for service delivery costs over time. There is also the danger that once communities have "paid" for their facility they consider that they have already fulfilled their responsibility.

Despite growing acceptance that full cost recovery from rural water users is an unrealistic goal, there is no doubt that community financing of operation and maintenance remains a crucial issue in the quest for sustainable rural water services. The assumption that poor people have no resources at all inevitably

Table 4. Tariff hierarchy example[a].

Level of cost recovery	Estimated monthly household tariff (US$)
O&M (direct costs only)	0.30
O&M (direct costs and indirect costs)	0.63
O&M (direct costs) + rehabilitation/expansion	0.74
O&M (direct and indirect costs) + rehabilitation/expansion	1.07
Recovery of initial construction costs[b]	+4.23

[a] Example for India Mark II hand pump for a community of 300 people in Ghana.
[b] Based on cost of US$10,000 for borehole, hand pump and all associated start-up costs paid over 10 years.

; to unsustainable subsidies and is usually inaccurate since many people are already paying a high : for sub-standard services (Evans, 1992). Indeed, the poorest people in developing countries pay ; on average per litre of water than their better off compatriots (Webb & Iskandarani, 2001). Most munities do have resources and hence the ability to pay (at least something) for service delivery; ever, the way in which those resources are managed will influence the ability of communities to ss resources when needed, and the value assigned to a water service will affect the willingness to pay services.

here are a number of key measures that need to be fulfilled to ensure sustainable community ncing:

ngoing costs must be calculated and this information must be packaged in a way that communities in understand in order to make informed decisions.
eople need to be convinced of the concept of paying for water through appropriate community ensitization.
ransparent and efficient financial management systems need to be developed.
Villingness to pay among communities needs to be sustained through ongoing institutional support nd promotion of income generation.
ncremental strategies to phase out unsustainable subsidies, and/or develop mechanisms for ustainable cross-subsidy, need to be developed.

sting O&M is the first step to ensure that communities are aware of ongoing costs and the financial nmitment required to sustain their water systems. This allows them to select the most appropriate nnology and system for them. Whatever financing system is to be used, it is essential that users are are of typical costs from the outset and that those responsible for management are assisted in setting listic and adequate water tariffs.

Convincing people to pay for water is often not easy in communities, especially where there is a tory of receiving services for free. Past activities may have reinforced the perception of poverty l dependency among communities, which retard efforts to encourage them to pay. Political erference can also be a significant barrier to sustainable community financing since politicians nmonly make promises of free services to communities for political gain (Komives & Stalker okopy, 2000). Changing attitudes can be difficult in such situations and requires considerable ie and skills.

Accountability and transparency can go a long way to convince community members to contribute to &M costs (Tayong & Poubom, 2002). It is important that users can see where their money is going and w it is being used, if they are to be convinced to contribute and to continue contributing. This is why it sometimes easier to raise funds for the installation of a new facility than for its maintenance. Users y be unclear about why they should pay and what their money is being used for. If the principle of ying for water can be instilled, however, this dilemma disappears.

Community financing strategies need to include appropriate mechanisms for revenue collection and rage and investment of revenue, as well as measures to sustain willingness to pay within the nmunity.

evenue collection

There are many different mechanisms by which maintenance funds can be collected and stored, and ocally appropriate systems should be developed through consultation with communities. The most ommon funding systems are:

- reactive financing
- monthly tariffs and
- pay-as-you-fetch.

Reactive financing simply means that when a system fails or breaks down the community or better-off households club together to pay for repair. *Monthly tariffs* are perhaps the most widespread system whereby each household (or adult) in the community is expected to contribute a given amount each month. *Pay-as-you-fetch* systems require a caretaker to be present at the facility at all times (except when it is locked) to collect water tariffs from the community. Users pay a fixed amount per container which is filled by the caretaker.

The advanced collection of maintenance funds does not necessarily shorten the downtime of a given water system (Batchelor *et al.*, 2000), although seasonal cash flow variations may have a big impact on whether finances can be raised rapidly (van Miert & Binamungu, 2001). Where household tariffs are paid monthly and funds are stored safely, such systems can be highly successful. Revenue collection can be conducted by CBOs or private service providers, but can be a time-consuming process, particularly where non-payers need to be chased up. Traditional leaders and respected community members can play an important role in exerting pressure and deciding where exemption or subsidy is appropriate. The most common problem encountered, however, is that willingness to pay among households is difficult to sustain and this often reduces over time, often because of a lack of trust or confidence in the water management body. Pay-as-you-fetch systems are undoubtedly the most successful in terms of revenue generated but are only possible where there is a year-round cash economy.

Storage and investment of funds

Since most rural African communities live from crisis to crisis and do not have a reliable year-round cash economy one of the major challenges in developing sustainable financing strategies is the need to establish functional mechanisms for storing funds in advance of breakdown. Where transparency and accountability are in place, maintenance funds may be stored in a bank account or with a treasurer. However, rural communities are often situated a long distance from the nearest bank, bank charges commonly rapidly eat away at the investment, or currency devaluation negates the link between funds and imported parts. An alternative strategy is for the treasurer to keep these funds for when they are needed, which relies on considerable self-discipline and the trust of the rest of the community.

In agriculture-based communities, money may be more readily available following harvests than at other times of the year. It is therefore important that alternative ways of storing resources are investigated so that funds can be raised when needed. Rather than use a bank account, communities can opt to run a cooperative whereby the water funds are used to purchase livestock or to support a

munity farm. Communal agricultural produce can then be sold when funds are required. This has the
d advantage of avoiding devaluation effects.

otating savings and credit associations (ROSCAs) are cooperative financing strategies which can be l to mobilize savings for very small amounts of working capital and have been practiced for centuries in y parts of the world. Some African examples of ROSCAs include *Susu* in Ghana, *Stokvel* in South ca, *Tontine* in most of francophone West Africa, "Merry-go-round" in Kenya, and *Chilemba* in Zambia lliamson & Donahue, 2001). ROSCAs are designed to assist members to save money and regulate their idity. This is achieved by creating relationships of debt between members whereby monthly tributions are allocated to each member on a rotational basis. Since the typical ROSCA member dislikes ng the other members they are driven to fulfil their commitment to the ROSCA more reliably than they ld be able to independently maintain a regular habit of saving money (Aliber, 2001).

raditional ROSCAs, such as the "Merry-go-round" scheme in Kenya, have been used to raise capital community contributions to construction and O&M costs for rural water systems (Harvey *et al.*, 3). Where there is a history of cooperative financing, it is often significantly easier to raise water enue. Such schemes can also be used to build up credit worthiness with financial institutions and erate capital for investment and income generation. There is, therefore, potential for the application ROSCAs to be expanded to meet long-term water supply rehabilitation and expansion costs. wever, this will only be successful if communities are convinced that this is their responsibility rather n that of government. There is no well-documented evidence to suggest that ROSCAs have been lied in such a way to date, but this issue requires further investigation.

vately-managed O&M

Whether systems are managed by the community or the private sector, many of the same issues rounding community financing apply. For rural water supplies which are managed by a private ntractor or individual rather than the community, users regularly pay the contractor to run and intain the system and may be less concerned about where the money goes and what it is used for, so g as the water supply continues to operate at the desired service level. The storage of funds becomes responsibility of the private company which removes one level of complexity at community level. is does not, however, remove problems which may occur owing to seasonal cash-flow fluctuations. vate contractors will also need to meet overheads and meet profit targets. These costs must be luded in estimating total O&M costs and setting household tariffs. However, where a company is ponsible for a large number of systems for many communities, the impact of these costs on each nmunity is likely to become very small. Given the negligible application of privately managed O&M tems in rural sub-Saharan Africa to date, however, it is not possible to assess their potential impacts community financing adequately.

taining willingness to pay

Services which rely on the users to finance ongoing running costs will only be sustainable if the lingness of users to pay is sustained. Community members who are willing to finance O&M costs in the initial stages may soon become unwilling to do so. There are a variety of possible reasons for this reduced willingness to pay:

- lack of transparency and accountability relating to the water management committee,
- no faults with the facility and therefore no clear reason for paying,
- dissatisfaction with water supply (location, time to queue, water quality/quantity),
- competition from cheaper water sources and
- change in individual priorities.

Perhaps the most effective mechanism that can be used to sustain willingness to pay is appropriate institutional support for communities. Where communities are regularly visited by an overseeing institution to monitor systems this reaffirms the need to contribute to the cost of O&M. The institution can advise communities on how to make best use of unspent funds through investment, can regulate water committees to ensure transparency, and can help to rectify any causes of dissatisfaction with a particular water system. Quarterly monitoring visits provide an ideal mechanism to identify problems early and find sustainable solutions.

The second measure that can assist greatly in sustaining willingness to pay relies on a major mind shift among community members. If water supply users understand that they must pay for water, rather than to maintain a system, many of the obstacles to sustained community financing disappear. Such a mindset needs to be established early on in the community consultation process and, where there are existing facilities installed under different programmes, this is likely to be difficult to achieve. New programmes, however, have the opportunity to develop awareness and place the emphasis on "water" rather than the "facility". If users accept from the outset that they have to pay for water from an improved water supply and that this will always be the case, financing is more likely to be sustained, providing that the service supplied meets the standard demanded by the users.

Another key measure to ensure sustained financing of O&M is to use water to generate income. Where water directly leads to income generation, the problem of community financing may become significantly less since water users have increased incentive to ensure that the system keeps operating and are more likely to have finances readily available to enable O&M. Water-related income generation ventures in rural areas include livestock watering, irrigation for market gardens, block making, beer brewing and food processing. There is little documented evidence, however, of successful income generation from systems designed primarily for the supply of drinking water.

Pro-poor financing strategies

The United Nations Committee on Economic, Cultural and Social Rights issued a statement in November 2002 declaring access to water a human right and stating that water is a social and cultural good, not merely an economic commodity (World Water Council, 2002). However, the necessary financing and governance structures to guarantee access to safe, sufficient and affordable water are commonly lacking (Mehta, 2004). In order to achieve this aim it is important to find ways in which to serve the poorest and most vulnerable, while ensuring that sufficient finances are generated to sustain services. As has been mentioned, full cost recovery for operation and maintenance from rural munities in Africa, at least on a large scale, has not been achieved to date. This indicates that capital recurrent costs are routinely subsidized by external support agencies or governments. This should be a cause for surprise. Most urban water authorities depend on subsidies to cover part of their ırrent costs and virtually all their capital spending on expansion and modernization (Winpenny, 3). There is, therefore, no logical reason why higher rates of cost recovery should be expected from .l water users, who are in general, poorer.

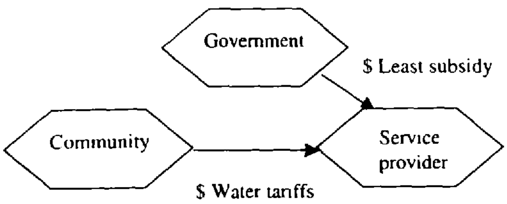
ubsidy in itself is not a threat to sustainability provided that the subsidies themselves are either sitional or sustainable. The World Panel on Financing Water Infrastructure recommends that sidies should be "targeted, transparent and, where they are intended to ease the transition to higher ffs, tapering" (Winpenny, 2003). Inherent within this statement is recognition of the fact that while ıe subsidies may act as a bridge to the generation of higher revenues, equally some subsidies may be ɹired on an indefinite basis. What is essential is that such subsidies are affordable in the long term and budgeted for accordingly.

ıst subsidy option

)ne way to ensure that the poor are adequately served is to offer direct subsidies to poor communities. ›se are likely to be partial rather than total subsidies, and in effect this is often what happens since rs rarely meet the full cost of O&M. A formalized version of this is the bidding for least subsidy ›roach (Figure 1). In this model private service providers bid for the minimum or least subsidy from /ernment to provide water systems at agreed service levels for a period of say, 10 to 15 years. These vate companies need to assess and negotiate the community contribution they will get for O&M. The /ernment then pays the minimum subsidy to the company and the communities pay their water tariffs. is model has not been applied to rural water services in Africa to date but its application to other tors, such as rural telecommunications (Cannock, 2001), demonstrates considerable potential for ere services are delivered by the private sector.

mmunity cross subsidy

Many poor rural people are currently subsidized by other more affluent members of their community. mmunity management systems often recognize that some households are unable to afford water iffs and therefore exempt them from payment (Harvey *et al.*, 2003). This is a sensitive issue since it ıy give rise to internal disagreement or envy and is open to abuse. It is, however, highly effective ıere community management is strong and allows the poorest and most vulnerable to be supported and



. 1. Least subsidy option.

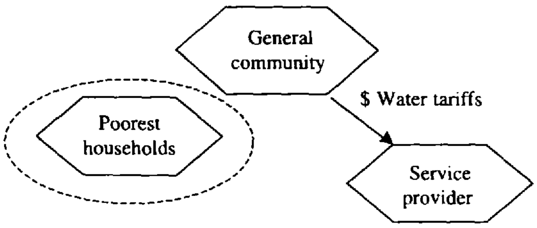


Fig. 2. Community cross subsidy.

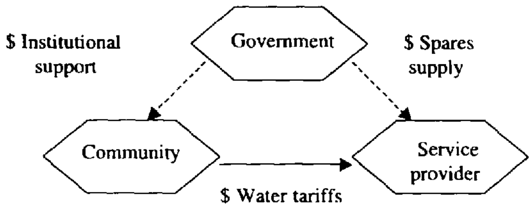


Fig. 3. Hidden subsidies (dashed).

protected by the rest of the community. The service provider in this case may be a CBO or private individual/organization (Figure 2).

This system of cross subsidy within a community is difficult to formalize and relies upon the goodwill and objectivity of the management committee. For privately managed water supplies a more formalized system is to apply individual means-tested water subsidies whereby the poorest households receive a government subsidy and pay less for water. The subsidy may be funded entirely by the government or from other users. This has been successfully implemented for urban water services delivered by the private sector (Gómez-Lobo, 2001) but has not yet been transferred to the rural sector.

Hidden subsidies

Some subsidies for operation and maintenance of rural water supplies are indirect or "hidden". These commonly include support for spare parts supply, storage and distribution, and monitoring, regulation and institutional support for communities. Here, the service provider may be a local mechanic who obtains spare parts from a local NGO or subsidized dealer (Figure 3). It may be accepted that some level of such subsidy is needed, particularly for institutional support, but where possible, attempts should be made to phase out hidden subsidies over time and these costs should be worked into long-term financial plans.

Conclusions

There is growing acceptance that full cost recovery for rural water services is an unrealistic goal, since the capital costs of water infrastructure provision remain beyond the means of most rural communities. Yet while communities are widely expected to finance recurrent operation and maintenance costs, this goal is still peing realized in many parts of sub-Saharan Africa. One of the reasons for this is an *ad hoc* approach to nating costs and establishing tariffs. If sustainable financing strategies are to be developed, it is essential the cost of ongoing service delivery is determined, so that communities, local authorities and lementing agencies are aware of the long-term costs involved and can plan accordingly.

)ne way in which this can be achieved is to develop a tariff hierarchy that provides estimates of the ffs required for different levels of cost recovery. This can be done only by conducting a nprehensive assessment of the maintenance, repair and rehabilitation needs for different water system nologies and costing these. The vast majority of implementing agencies do not do this and sequently it is unclear what selected tariffs can be expected to cover and what additional financing y be required. Unless this situation changes, rural water systems are likely to continue rapidly to fall) disrepair and the need for rehabilitation projects is likely to continue *ad infinitum*.

The research in Ghana indicated that direct O&M costs are generally affordable for rural communities that there is a need to take action to sustain willingness to pay and to develop appropriate community ncing strategies which are matched to the specific characteristics of communities. These strategies st consider both how water revenue is collected and also how it is stored or invested.

The costs of institutional support from local government authorities (or substitute agencies) need to be t by public financing and must be budgeted for accordingly. If private sector service delivery becomes re widespread, it is possible that this can be met from tax revenue raised from end users, but this nains a far-off goal at present. The costs of rehabilitation and expansion of water systems can, in ory, be met by user communities but this raises tariffs significantly and is largely dependent on nmunity acceptance of the need to pay for water. This also makes the need for appropriate investment water revenue even more crucial and new approaches need to be investigated.

There is a need for realism from all stakeholders to identify what costs can be met by water users and what sts need to be met by national or external support. Just as the vast majority of urban water services require ne form of subsidy, so do rural water services. This issue cannot be avoided by pretending that the goal of st recovery for ongoing running costs is currently realistic. There is a need for policy makers and strategic nners in international development agencies and national governments to face up to this issue. They will ly do so if sector professionals are prepared to calculate the real costs involved in service delivery and to velop and advocate realistic financing strategies, which will almost certainly need to include targeted and nsparent subsidies, at least for the foreseeable future.

:knowledgements

The initial research for this paper was conducted as part of a Knowledge and Research (KaR) project iuidelines for Sustainable Hand pump Projects in Africa" (R7817), funded by the Department for ernational Development (DFID) of the British Government, and conducted by the Water, Engineering d Development Centre (WEDC), Loughborough University. Opinions noted within this paper do not cessarily represent those of DFID or the project team but are solely those of the author.

:ferences

ber, M. (2001). Rotating savings and credit associations and the pursuit of self-discipline. In *African Review of Money Finance and Banking, 2001*. "Giordano dell'Amore" Foundation, Milan, 1 p.

Annan, K. A. (2000). *"We the Peoples" The role of the United Nations in the 21st Century*. United Nations, New York.

Batchelor, S., McKemey, K. & Scott, N. (2000). *Exit Strategies for Resettlement of Drought Prone Populations (Project Technical Report)*. Gamos Ltd, Reading.

Baumann, E. (2005). *Common RWSN Context*. Discussion Paper. SKAT, St. Gallen, Switzerland.

Bernage, F. (2000). Local private sector involvement: the Mauritania experience. Paper presented at *SKAT/HTN Workshop on Civil Society and Government Partnerships in RWS*. Hyderabad, India, March 2000. SKAT, Switzerland.

Cannock, G. (2001). Expanding rural telephony: output-based contracts for pay phones in Peru. In *Contracting for Public Services: Output-based aid and its applications*. Brook, P. J. & Smith, S. M. (eds). The World Bank, Washington DC.

Carter, R. C., Tyrrel, S. F. & Howsam, P. (1999). Impact and sustainability of community water supply and sanitation programmes in developing countries. *Journal of the Chartered Institute of Water and Environmental Management, 13*, 292–296.

Deverill, P., Bibby, S., Wedgwood, A. & Smout, I. (2002). *Designing Water Supply and Sanitation Projects to Meet Demand in Rural and Peri-Urban Communities: Book 1. Concept, principles and practice*. WEDC, Loughborough University.

DWD (2002). *Rural Water and Sanitation Operation Plan: 20022007*. Version 1, September 2002, Directorate of Water Development, Ministry of Water, Lands and Environment, The Republic of Uganda.

Evans, P. (1992). *Paying the Piper: an overview of community financing of water and sanitation*. IRC, Delft, The Netherlands.

Fonseca, C. (2003). Cost recovery: taking into account the poorest and systems sustainability. In *International Congress Proceedings of the International Congress Watershed Management for Water Supply Systems* 29 June–3 July 2003. American Water Resources Association, New York, p. 1.

Fonseca, C. & Cardone, R. (2004). *Analysis of Cost Estimates and Funding Available for Achieving the Millennium Development Goals Targets for Water and Sanitation*. WELL Project 1.3, WELL, Loughborough University.

Fonseca, C. & Njiru, C. (2003). Financing and cost recovery: what happens after construction? *Proceedings of 29th WEDC Conference, Abuja, Nigeria, 2003*. Harvey, P. A. (ed). WEDC, Loughborough University, pp. 242–244.

Gómez-Lobo, A. (2001). Making water affordable: output-based consumption subsidies in Chile. In *Contracting for Public Services: Output-based Aid and its Applications*. Brook, P. J. & Smith, S. M. (eds). The World Bank, Washington DC, pp. 23–30.

Harvey, P. A. & Reed, R. A. (2004). *Rural Water Supply in Africa: Building blocks for sustainability*. WEDC, Loughborough University.

Harvey, P. A., Ikumi, P. N. & Mutethia, D. K. (2003). *Sustainable Handpump Projects in Africa: Report on Fieldwork in Kenya*. WEDC, Loughborough University.

IRC (2002). *Participatory Learning and Action Initiative*. IRC, Delft, The Netherlands.

Komives, K. & Stalker Prokopy, L. (2000). *Cost Recovery in Partnership: Results, attitudes, lessons and strategies*. BPD Water and Sanitation Cluster, London.

Lane, J. (2004). *Rural Water Supply and Sanitation in Africa*. presented at the Global Learning Process on Scaling up Poverty Reduction Shanghai Conference, May 25–27, 2004. Water and Sanitation Program, World Bank.

MacDonald, D. A. & Pape, J. (2002). *Cost Recovery and the Crisis of Service Delivery in South Africa*. Human Science Research Council, Cape Town, South Africa.

Mehta, L. (2004). *Financing Water for All: Behind the border policy convergence in water management*. IDS Working Paper 233. IDS, Sussex University.

Nedjoh, J., Thogersen, J. & Kjellerup, B. (2003). Challenges of O&M in the sustainability of rural water facilities. In *Proceedings of 29th WEDC Conference, Abuja, Nigeria, 2003*. Harvey, P. A. (ed). WEDC, Loughborough University, pp. 126–129.

RWSN (2005). *RWSN Strategy Paper: Sustainable Handpumps*. SKAT, St. Gallen, Switzerland.

Schouten, T. & Moriarty, P. (2003). *Community Water, Community Management – From system to service in rural areas*. ITDG Publishing/IRC, London.

Tayong, A. & Poubom, C. (2002). *Convincing People to Pay for Water: Nkouondja in Cameroon*. IRC, Delft, The Netherlands.

van Beers, P. (2001). Leasing, a new handpump O&M concept. In *Proceedings of 27th WEDC Conference, Lusaka, Zambia, August 2001*. Scott, R. (ed). WEDC, Loughborough University, pp. 413–415.

van Miert, T. & Binamungu, D. (2001). *The Shinyanga Experience: Water user group concept as a sustainable management system for hand pump wells*. SKAT, St. Gallen, Switzerland.

b, P. & Iskandarani, M. (2001). *The poor pay much more for water and use much less*. Water and Sanitation Update, ɜtwas, Nairobi.

ɡwood, A. & Sansom, K. (2003). *Willingness-to-pay Surveys – A Streamlined Approach: Guidance notes for small town ɪter services*. WEDC, Loughborough University.

O (2000). *Tools for Assessing the O&M Status of Water Supply and Sanitation in Developing Countries*. World Health rganization, Geneva.

O/UNICEF (2004). *Meeting the MDG Drinking Water and Sanitation Target: A mid-term assessment of progress*. World ealth Organization, Geneva.

liamson, J. & Donahue, J. (2001). *A Review of the COPE Program and its Strengthening of AIDS Committee Structures*. isplaced Children and Orphans Fund, USAID, Washington DC.

penny, J. (2003). *Financing Water for All*. Report of the World Panel on Financing Water Infrastructure. World Water ouncil/Global Water Partnership.

rld Water Council (2002). *UN Consecrates Water as Public Good, Human Right*. World Water Council, www. orldwatercouncil.org/download/ UN_water_public_good.pdf.

rld Water Council (2004). *Analysis of the 3rd World Water Forum*. World Water Forum, Secretariat of the Third World /ater Forum.

4. COMMUNITY AND SOCIAL ASPECTS

doi 10.1093/cdj/bsl001
Advance Access publication 10 February 2006

Community-managed water supplies in Africa: sustainable or dispensable?

Peter A. Harvey and Robert A. Reed

Abstract Over the past two decades, community management has become the prevalent model for management of rural water supplies throughout sub-Saharan Africa. Despite its widespread popularity among donors and implementing agencies, low water supply sustainability levels throughout the sub-continent indicate that it is not the panacea it is often presented to be. There is a strong need to distinguish between 'community participation' which is a prerequisite for sustainability and 'community management' which is not. If community management systems are to be sustainable, they require ongoing support from an overseeing institution to provide encouragement and motivation, monitoring, participatory planning, capacity building, and specialist technical assistance. If such support is not available, alternatives such as household water supplies and private sector service delivery should be considered.

Introduction

The concept of community management has gained widespread acceptance throughout the international development sector and is currently applied in the vast majority of rural water supply projects and programmes in sub-Saharan Africa (IRC, 2003). The basic principles behind this concept are that the community that benefits from an improved water supply should:

- have a major role in its development,
- own the water system or facility, and
- have overall responsibility for its operation and maintenance (O & M).

In general, this is fulfilled through the formation of a community water committee that is responsible for operating the system, setting and collecting water tariffs, and managing maintenance and repair activities.

Community members are normally expected to contribute to initial system installation costs and to meet all ongoing maintenance and repair costs through the regular payment of appropriate water tariffs.

Despite the blanket application of community management of rural water supplies in sub-Saharan Africa, the sustainability of such interventions remains woefully inadequate. It is currently estimated that 35% of all rural water systems in sub-Saharan Africa are not functioning (Baumann, 2005). Recent figures from individual African countries indicate operational failure rates of between 30 and 60% (Hazelton, 2000; DWD, 2002; Sutton, 2005). Many of the reasons for low levels of sustainability are related to community issues, such as limited demand, lack of affordability or acceptability among communities, perceived lack of ownership, limited community education, and limited sustainability of community management structures (Carter, Tyrrel, and Howsam, 1999). Unless sustainability levels can be vastly improved, the Millennium Development Goal target to halve the proportion of people without sustainable access to safe water by the year 2015 will not be achieved.

Given this situation, it is important to understand why community management has been applied in so many cases and why it has had such limited success. This paper, based primarily on research in Ghana, Kenya, Uganda, and Zambia, attempts to question the widespread faith placed in community management, to determine whether, and under what conditions, it contributes to sustainable rural water services and whether there are alternative solutions that are largely being ignored at present.

Historical perspectives

The theoretical frameworks that underpin community management are various, including neoliberal perceptions on reduced state involvement, water as a basic human right, water as an economic good, and people first and empowerment approaches (IRC, 2003). However, although such development-based principles may have contributed to the prevalence of community management, in the opinion of the authors, these are secondary to three fundamental reasons:

1. Poor service delivery and performance by government institutions.
2. Suitability to the project approaches adopted by non-governmental organizations (NGOs) and donors.
3. Western 'cultural idealization' of communities in low-income countries.

Prior to the introduction of community management in the 1980s, most rural water supplies were 'supply-driven' and delivered and managed by government institutions. The efficiency of such management systems was generally poor because of limited government capacity and commitment. Consequently, sustainability levels were low and it was widely recognized that there was a need to develop more effective mechanisms for management of ongoing water supply O&M. The community management concept appealed to many governments, who were already committed to decentralization and overstretched in attempting to deliver and maintain rural services, as it relinquished them of their responsibility for O&M (IRC, 2003).

The second reason behind community management was the 'project approach' adopted by most bilateral organizations and NGOs, whereby the implementing agency would construct a number of water systems as part of a project and then leave the project area after several months or years. Community management, therefore, became a convenient concept for shifting responsibility for ongoing O&M, and hence sustainability of services, from facility-provider to end-user. By sensitizing and mobilizing the community to instil a sense of ownership and responsibility, and handing over the water facility to them to manage, agencies were able to abrogate responsibility with a clear conscience.

The third reason is related to the hegemonic nature of development. Community management was a concept developed predominantly in the West, where there has undoubtedly been a tendency to idealize communities in low-income countries, and to view them on the basis of simplistic 'cultural differences' rather than to judge them by our own standards and values (Pilger, 2002). Rural water systems in high-income countries are not generally managed successfully by communities, so why should there be an automatic expectation that they can be in low-income countries? Although it is accepted that some rural communities in sub-Saharan Africa have a history of community co-operation and ownership which is accordant with the concept of community management, this is by no means true of all rural communities. The community management model, however, has been applied to all communities without such distinction, based on an idealized generalization.

Community 'participation' versus 'management'

The importance of community participation and community management in rural water supply is often emphasized, yet perceptions of what these terms mean vary greatly. Community participation is a consultative empowerment process designed to establish communities as effective decision-making entities. This broadly means that the community to benefit from an improved water supply is involved in information sharing, consultation, decision-making, and initiating action (Guijit and Shah, 1998). Community participation can be stimulated by a community itself, or by others, and begins with dialogue among members of a community to determine who, what, and how issues are decided, and to provide an avenue for everyone to participate in decisions that affect their lives. Information sharing is essential so that the community is able to make informed decisions and act upon them.

An essential component of community participation is to define the 'community' and to establish an appropriate mechanism for decision-making. In relation to rural water supply, a community is likely to be defined by the area to which a given water system can realistically serve. This is not necessarily the same as a pre-existing community defined by village, ethnic, or family groups. Many communities benefiting from a water supply will be made up of people of different families, clans, ethnic groups, religious groups, and socio-economic groups. Therefore, it should not be taken for granted that a group of people has the internal resources, common interest, or sense of solidarity to either initiate action or sustain the management of a facility (DeGabriele, 2002).

Community participation involves 'mobilizing' a community to become involved in planning and implementing a water supply project. This may take considerable time and should not be rushed. Some communities may become actively involved in water supply activities within a matter of weeks; others may take several months or years. Community participation (including the simplest level of involvement) from early on in a water supply project enhances the future sense of ownership, but ongoing motivation is required for continuing participation (Batchelor, McKemey, and Scott, 2000). This is of key importance; just because a community has participated in the planning process does not mean that it will sustain participation in ongoing service delivery or that it will successfully manage its water supply. Community participation does not *automatically* lead to effective community management, nor should it have to. Services that are not to be managed by the community should still follow on from effective community consultation and participatory planning. Community *participation* is a prerequisite for sustainability, i.e. to achieve efficiency, effectiveness, equity, and replicability, but community *management* is not.

Community management can be viewed as a form of community participation (Wegelin-Schuringa, 1998), but is distinct as illustrated in Figure 1. Community management is a bottom-up development approach whereby community members have a say in their own development and the community assumes control – managerial, operation, and maintenance responsibility – for the water system (Doe and Khan, 2004). This means that the beneficiaries of the water supply have full responsibility, authority, and control over it

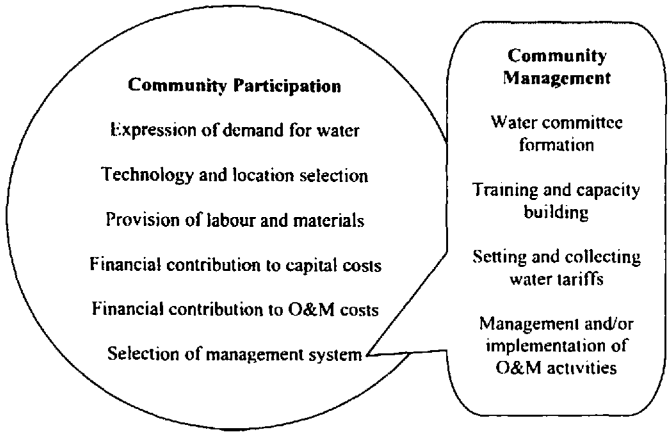


Figure 1 Segregated Aspects of 'Participation' and 'Management'

(McCommon, Warner, and Yohalem, 1990). Community involvement in system construction began in the 1970s, which developed into community participation in decision-making and maintenance in the 1980s, which then developed into community management in the late 1980s and 1990s (IRC, 2003). During this process, the responsibility for service provision has gradually moved from national government to local people. Community management usually relies on the formation of a water committee which is responsible for all management issues related to water supply in the community. Where projects use existing community management structures, such as community co-operatives, development committees, or traditional leadership structures, the sustainability of the water point is better than where a new committee is set up (Batchelor, McKemey, and Scott, 2000). An essential role of the implementing agency is to facilitate the formation of an appropriate management body and enable the community to take care of its system after they have left (IRC, 2003).

Some commentators argue that the main reason for advocating community management is that the people for the projects should have a major say in how the scheme is constructed and managed (McCommon, Warner, and Yohalem, 1990; Wood, 1994; Mayo and Craig, 1995). If this is the case, then they should also be free to decide that they do not wish to manage the system themselves, in which case there is active community 'participation' but not 'management'. Doe and Khan (2004) claim that community development is operationalized through community management, but this need not be the case. Community development is operationalized by empowering communities to take control of their development. This means that they should also have the right to choose not to manage their water supply should they so wish.

Limitations

The fact that low rural water supply sustainability levels remain throughout sub-Saharan Africa indicates that there are severe limitations to current approaches to community management. Most problems with community management do not occur immediately after the commissioning of an improved water supply but sometime later, normally within 1–3 years. The reasons for the breakdown of management systems are numerous. In a survey of several hundred communities in the study countries, the six most commonly cited causes were as follows:

1. Community management often relies on voluntary inputs from community members, which people may do for a while but are reluctant to do in the long term; there are often no long-term incentives for community members.
2. Key individuals on the water committee leave the community or die, and there is no mechanism to replace them with trained individuals.
3. The community organization charged with managing the water supply loses the trust and respect of the general community. This may be related to a lack of transparency and accountability, and lack of regulation by a supporting institution (e.g. local government).
4. Failure by community members to contribute maintenance fees leads to disillusionment among committee members who abandon their roles. This may be due to a lack of legal status and authority of the water committee or lack of community cohesion.
5. Communities have no contact with local government (or the implementing agency) and feel that they have abrogated responsibility for service provision; they therefore feel abandoned and become demotivated.
6. Communities are too poor to replace major capital items when they break down.

Another key limitation to community management is the widespread perception that 'ownership' is a prerequisite for community management and is the key to sustainability (Knudsen and Tidemand, 1989; Cotton and Taylor, 1994; Niedrum, 1994; Bossuyt and Laporte, 1995). The prevailing wisdom supports the idea that ownership of the water supply facility will lead to a responsibility for its management, which will lead to a willingness to manage, which in turn will lead to a willingness to meet ongoing O&M costs. In reality, the research showed that there is no *automatic* relationship between these aspects. Just because a community owns a facility does not necessarily mean that it will acquire a sense of responsibility for its management, nor does it guarantee a willingness to manage or pay for its O&M.

The reverse of this can also be said to be true, i.e. the fact that a community is willing to pay for O&M does not necessarily mean that they have a strong sense of ownership. Of sixty communities visited in Zambia, 82% expressed a strong sense of ownership of their water supply, but the operational failure rate among these communities was not lower than among those that did not express such a sense of ownership. Although it is accepted that the term 'ownership' is often applied in a broader sense than legal ownership of an asset, it is essential that implementers are disabused of this common misconception. Although these links may exist in some cases, ownership in itself is not the 'key' to sustainability.

The issue of communal ownership is very different to individual ownership, yet it is a common mistake to view them in the same way. Where an individual owns a water system, for example, responsibility for its maintenance is clear and he or she is likely to ensure that it keeps going to maintain a ready supply of water. Where a community owns the system, the same logic does not necessarily hold true, for the following reasons:

- There may be no definition of what constitutes the 'community' and it may have no clear or legal identity.
- The location of the facility is unlikely to be equidistant from all users and hence true equity is impossible to achieve.
- The ability to pay for the service may vary greatly within the community and the fact that each household should contribute the same amount may be seen as 'unjust' by some.
- Disagreements and distrust between different families or individuals can make the very concept of 'community' difficult to accept.
- The facility or system may be installed on land which belongs to an individual or the government, resulting in a widespread perception that it does not truly belong to the community.
- Some members of a community may believe that water supply should be a government service and disagree with the concept of community ownership and responsibility.

It is crucial to note that ownership is not in itself the answer to sustainable community-managed water services. Rather, it is a complex issue which requires in-depth consultation to understand. Where ownership issues are difficult and it is unlikely that a community will establish a strong sense of ownership of a particular facility (due to legal, land-ownership, or community constraints), it may be more effective to abandon the desire to achieve community ownership and to develop a *sense of responsibility* for financing the upkeep of the facility. Instilling an understanding of the need to pay for water is one way in which this has been achieved in parts of Ghana, Kenya, and Uganda, where communities pay a caretaker each time they collect water from the system. This can be applied whether community ownership is strong or not, and even in cases where the water system is owned by a private individual or enterprise (Harvey and Reed, 2004).

Potential solutions

The potential solutions to the limited success of community-managed rural water supplies can be divided into three key categories:

1 Provision of institutional support to communities,
2 Provision of household and small user-group water supplies, and
3 Implementation of private sector service delivery models.

Institutional support to communities

The assumption that supporting community-managed O&M is a less onerous task than running a centralized maintenance and repair system has not been borne out in the field (WHO, 2000) and at present there is little evidence to suggest that governments have facilitated community management effectively on their own (Colin, 1999). This may be because government authorities and support agencies do not understand the need for appropriate support systems, perhaps in part because there has been a widespread misconception that services can be managed autonomously by communities and that governments can be side-stepped in the process of service delivery by external support agencies. This common lack of understanding among governments also explains why many government policies do not give sufficient attention to this issue. This can be seen from the rural water supply strategy documents of all four study countries which stress that it is communities only, not governments, that are responsible for management, operation, and maintenance of water supplies. The national policy for water resource management in Kenya goes as far as to state that water systems should be 'self-sustaining' and beneficiaries should 'take full responsibility' (MWR, 1999). Given that access to water is a fundamental human right (World Water Council, 2002), governments should not neglect their responsibility to enable communities to realize this.

Evidence from each of the study countries shows that community management is sustainable only where a strong local institution is in place to support communities. The highest operational sustainability levels were recorded in specific districts in Ghana, Uganda, and Zambia, where local government and/or NGOs play a dynamic role in supporting communities. Appropriate institutional support comprises the following components:

- encouragement and motivation,
- monitoring and evaluation,

- participatory planning,
- capacity building, and
- specialist technical assistance (including financial support where required).

An appropriate institution can provide ongoing support to help preempt many of the problems associated with community management and to find solutions to them by working in partnership with communities. Such support might include regulation of management committees, developing sustainable and transparent incentives for committee members, refresher training for existing members, training of new members, consultation with disenfranchised groups and individuals within communities, conflict resolution, and designation of committees as legal entities. Provision of technical expertise by such an institution is also essential to ameliorate complex technical problems that are beyond the management and financial capabilities of the community. In one area of Ghana, where a strong local NGO made visits to all communities on a quarterly basis to provide this support, 86% of all rural water systems in the forty-four communities surveyed were functioning. Similarly, districts in Zambia with strong district water and sanitation teams (consisting of government and NGO personnel), which met and monitored communities regularly, demonstrated significantly higher sustainability levels than those of districts with weaker institutional set-ups.

In general, stronger institutions than at present are needed to promote and support community management, and adequate funding is still required for agencies to be able to perform their essential supportive role (Davis and Brikké, 1995). This is backed up by new strategies developed by implementing agencies that recognize the need for institutional support and the need to budget for this accordingly (Nedjoh, Thogerson, and Kjellerup, 2003). Such support is not a stopgap or short-term measure, but should be indefinite.

The term 'scaling-up community management' is now increasingly used to refer to the need to increase sustainability and coverage by creating institutional frameworks for community-managed services, using a learning approach which includes all relevant stakeholders and allows for local context (Schouten and Moriarty, 2003). This requires political support and involves calculating the full costs of implementing the community management model; promoting appropriate low-cost technology; building capacity at all levels; and providing adequate financing from communities, government, and the private sector (Lockwood, 2004). Institutional support is best provided by a local government institution, although where this is not possible, for example, where there is no effective government, an NGO or stakeholder group can fulfill this role.

Household alternatives

Community members are often less willing to contribute a modest amount to the cost of a community water supply than they are to pay a significantly greater amount for a private household supply (Sutton, 2003). Although it is not possible to provide household options in all instances, where it is, the obstacles to sustainability created by lack of trust, cohesion, and co-operation within communities can be greatly reduced through their development.

Many African countries report low coverage rates for access to safe water, yet the many millions of people who are 'unserved' rely on water from traditional sources that they have found or developed for themselves. These include hand-dug wells, scoop-holes, and surface water sources such as rivers and streams. It is estimated that some 33% of people (140 million) in rural sub-Saharan Africa rely on traditional hand-dug wells (Sutton, 2005). Such water sources may be household-based or used by small groups (consisting of several families). These can often be developed and upgraded to provide sustainable access to safe water by improving and protecting traditional sources, encouraging household water treatment, and promoting simple alternatives such as rainwater harvesting. Comprehensive information on all feasible options should be provided to community members in order for them to decide on the most appropriate technology and service level for them. In many cases, low-cost household or small-group options are preferred (Breslin, 2003; Harvey and Kayaga, 2003). Such an approach offers greater security to the poor while reducing dependency on remote technologies.

Private sector alternatives

Simply because a community owns a water supply facility, makes an initial contribution to its installation, and finances O&M does not mean that it must manage the supply facility. Implementers should take a flexible approach to management and investigate alternative options to community management. Current low levels of sustainability in South Africa, where government management of low-cost rural water systems (such as hand pumps) persists, suggest that a return from community management to centralized public sector systems would not lead to an increase in sustainability (Harvey and Kayaga, 2003). However, private sector management options may provide more sustainable frameworks in some cases. Such options should be discussed with communities who may be only too happy to relinquish control. This should not be seen as disempowerment, because the community still has the freedom to express its preferences and, if it chooses, to regain control.

A survey of rural communities in Uganda revealed that although 69% of communities thought they should own the water system, 88% expressed no general objection to it being managed by a local private sector enterprise, although 59% expressed no objection so long it did not cost more to the community. Although this was based on only a small sample size, it illustrates the fact that communities may not be as opposed to private sector involvement as is often believed. Interestingly, there was far more resistance to indigenous private sector involvement from government officials than from communities. Evidence from the small number of African countries where private sector management models have been implemented suggests that in some cases it may be a more viable alternative than community management and that further application is warranted (Bernage, 2000; van Beers, 2001).

Conclusions

In answering the question 'Community-managed water supplies in Africa: sustainable or dispensable', although community *participation* remains indispensable for sustainable rural water provision in Africa, community *management* does not. In some cases it is indeed 'dispensable', because there are alternative management models that can be effectively applied. That is not to say that community management should be discarded in all situations, but rather that it can only become *sustainable* with appropriate institutional support, which is currently lacking in most cases.

- Community management of rural water supplies in Africa has not delivered satisfactory levels of service sustainability. Donor practices and government policies commonly fail to recognize that communities cannot be isolated to manage their own water supplies and that in many cases there are viable alternatives.
- Greater agency accountability and greater government accountability are needed in the ongoing provision of rural water services. This means that implementing agencies, both governmental and non-governmental, must recognize the need for long-term support for community management and develop strategies to provide this accordingly. All implementers should desist from following the project approach of the past.
- There is a need for realism rather than idealism when working with rural communities in sub-Saharan Africa. Communities and individuals within communities should be judged by the same standards that their educated middle-class compatriots and those in the West judge themselves. Recognition of community heterogeneity and the rights and preferences of individuals is paramount to this.

- Current misconceptions relating to ownership need to be challenged. Although ownership may contribute to sustainability in many cases, it should not be made a goal in itself with the implicit assumption that it is the principal prerequisite for sustainable water provision. The differences between communal and individual ownership must also be understood.
- Incentives for community management should be assessed for individual communities, and household and private sector options should be explored where there is resistance to community management or limited capacity for its successful implementation.

If user communities are to be truly empowered and granted true decision-making authority, they should be given comprehensive information needed to make informed decisions, without being pressured to follow the preferences of the facilitator. Communities and households should be free to select technology and service levels that suit them. They should also be free to select the most appropriate management system for O&M, including the option not to manage this themselves should they so wish. Unless such an approach is taken, use of the term 'community development' in relation to rual water supply will remain rhetoric rather than reality.

Acknowledgements

This paper is an output from the Knowledge and Research (KaR) project 'Guidelines for Sustainable Handpump Projects in Africa' (R7817), funded by the Department for International Development (DFID) of the British Government, and conducted by the Water, Engineering and Development Centre (WEDC), Loughborough University. Opinions noted within this paper do not necessarily represent those of DFID but are solely those of the authors.

Peter Harvey is a Programme Manager and Robert Reed is a Senior Programme Manager at the Water, Engineering and Development Centre (WEDC), Loughborough University, Loughborough, UK.

Address for correspondence: P.A.Harvey@lboro.ac.uk

References

Batchelor, S., McKemey, K. and Scott, N. (2000) *Exit strategies for resettlement of drought prone populations*, Project Technical Report, Gamos Ltd., Reading, UK.

Baumann, E. (2005) *Common RWSN context*, Discussion Paper, St. Gallen, SKAT/RWSN.

Bernage, F. (2000) 'Local private sector involvement: the Mauritania experience', paper presented at SKAT HTN Workshop on Civil Society and Government Partnerships in RWS, Hyderabad, India, March 2000, SKAT, Switzerland.

Bossuyt, J. and Laporte, G. (1995) Combining ownership and accountability in technical cooperation, *International Journal of Technical Cooperation*, **1**(1), 107–116.

Breslin, E. D. (2003) The demand-responsive approach in Mozambique: why choice of technology matters, *Waterfront*, Issue 16, Fall 2003, UNICEF, New York.

Carter, R. C., Tyrrel, S. F. and Howsam, P. (1999) Impact and sustainability of community water supply and sanitation programmes in developing countries, *Journal of the Chartered Institute of Water and Environmental Management*, **13**, 292–296.

Colin, J. (1999) *Lessons learned from village level operation and maintenance*, WELL Study Task 162, WELL, WEDC, Loughborough University, UK.

Cotton, A. P. and Taylor, W. K. (1994) Community management of urban infrastructure in developing countries, *Proceedings of the Institution of Civil Engineers, Municipal Engineer*, **103**(4), 215–224.

Davis, J. and Brikké, F. T. (1995) *Making Your Water Supply Work: Operation and Maintenance of Small Water Supplies*, IRC, Delft, The Netherlands.

DeGabriele, J. (2002) *Improving community based management of boreholes: a case study from Malawi*, BASIS, University of Wisconsin-Madison, USA.

Doe, S. R. and Khan, M. S. (2004) The boundaries and limits of community management: lessons from the water sector in Ghana, *Community Development Journal*, **39**(4), 360–371.

DWD (2002) *Issue Paper 1: Overview of the Water Sector, Reform, SWAP and Financial Issues*, Directorate of Water Development, Ministry of Water, Lands and Environment, The Republic of Uganda.

Guijit, I. and Shah, M. K. (1998) *The Myth of Community – Gender Issues in Participatory Development*, IT Publications, London, UK.

Harvey, P. A. and Kayaga, S. M. (2003) *Sustainable Handpump Projects in Africa: Report on Fieldwork in South Africa*, WEDC, Loughborough University, UK.

Harvey, P. A. and Reed, R. A. (2004) *Rural Water Supply in Africa: Building Blocks for Handpump Sustainability*, WEDC, Loughborough University, UK.

Hazelton, D. (2000) *The development of community water supply systems using deep and shallow well handpumps*, WRC Report No. TT132/00, Water Research Centre, South Africa.

IRC (2003) *Community Water Supply Management: History of a Concept*, IRC, Delft, the Netherlands.

Knudsen, H. and Tidemand, P. (1989) *Debatten om folkelig deltagelse, Den nye verden*, **22**:3 Copenhagen, Denmark.

Lockwood, H. (2004) *Scaling up community management of rural water supply*, Thematic Overview Paper, IRC, Delft, the Netherlands.

Mayo, M. and Craig, G. (eds) (1995) *Community Empowerment*, Zed Books, London.

McCommon, C., Warner, D. and Yohalem, D. (1990) *Community Management of Rural Water Supply and Sanitation Services*, The International Bank for Reconstruction and Development/The World Bank, Washington, DC.

MWR (1999) *Sessional Paper No. 1 of 1999 on National Policy on Water Resources Management and Development*, April 29, 1999, Ministry of Water Resources, Republic of Kenya.

Nedjoh, J., Thogersen, J. and Kjellerup, B. (2003) Challenges of O&M in the sustainability of rural water facilities, in Harvey, P. A. (ed.) *Proceedings of 29th WEDC Conference*, Abuja, Nigeria, 2003, WEDC, Loughborough University, UK.

Niedrum, S. (1994) Community management – lessons from Rwanda, *Affordable Water Supply and Sanitation, Proceedings 20th WEDC Conference*, Colombo, Sri Lanka, 1995, WEDC, Loughborough University, UK.

Pilger, J. (2002) *The New Rulers of the World*, Verso, London.

Schouten, T. and Moriarty, P. (2003) *Community Water, Community Management – From System to Service in Rural Areas*, IRC/ITDG Publishing, London.

Sutton, S. (2003) Why think of smaller units for rural water supply? Household and small community solutions, Overview presentation at the Fourth HTN Forum, 2–5 June 2003, Durban, South Africa.

Sutton, S. (2005) The sub-Saharan potential for household level water supply improvement, *Maximizing the Benefits from Water and Environmental Sanitation, 31st WEDC Conference*, Kampala, Uganda, 2005, WEDC, Loughborough University, UK.

van Beers, P. (2001) Leasing, a new Handpump O&M concept, in Scott, R. (ed.) *Proceedings of 27th WEDC Conference*, Lusaka, Zambia, August 2001, WEDC, Loughborough University, UK.

Wegelin-Schuringa, M. (1998) *Community management models for small scale water supply systems*, Paper for Discussion Workshop on Public–Private Partnerships in Service Provision for Community Managed Water Supply Schemes, Kakamega, Kenya, 7–10 December 1998.

WHO (2000) *Tools for Assessing the O&M Status of Water Supply and Sanitation in Developing Countries*, World Health Organization, Geneva, Switzerland.

Wood, M. (1994) Community Management of Rural Water Supplies, *Waterlines*, **12**(3), 6–9.

World Water Council (2002) UN Consecrates Water as Public Good, Human Right, accessed at: www.worldwatercouncil.org.

5. TECHNOLOGY

The case for the rope-pump in Africa: A comparative performance analysis

P. A. Harvey and T. Drouin

ABSTRACT

The conventional handpump is the most popular technology choice for improved potable water supplies in rural sub-Saharan Africa. To date, however, it has failed to deliver satisfactory levels of sustainability, largely due to inadequate maintenance capacity. An alternative option to standardised imported handpumps is the locally manufactured rope-pump, which is considerably cheaper and easier to maintain but has been rejected in the past due to fears of impaired water quality. This paper presents the key aspects of a study in northern Ghana which compared the performance of rope-pumps with that of conventional handpumps, to determine whether or not the rope-pump provides a viable alternative for community water supplies across the sub-continent. User interviews, sanitary surveys, water quality analyses and technical performance measurements were used to develop a comparative performance analysis for the two pump types. The findings of the study indicated that the rope-pump out-performed the conventional handpump on the majority of counts and that, contrary to widespread perceptions, there was no significant difference between pump types with respect to the impact on microbiological water quality. Consequently, the rope-pump provides a significant technological opportunity to improve water supply sustainability in Africa.

Key words | developing countries, pumps, rural water supply, water quality

P. A. Harvey (corresponding author)
T. Drouin
Water, Engineering and Development Centre (WEDC),
Institute of Development Engineering,
Loughborough University,
Loughborough, LE11 3TU, UK
Tel 01509-228743
Fax. 01509-211079
E-mail *P A Harvey@lboro ac uk*
website *http //wedc lboro ac uk*

INTRODUCTION

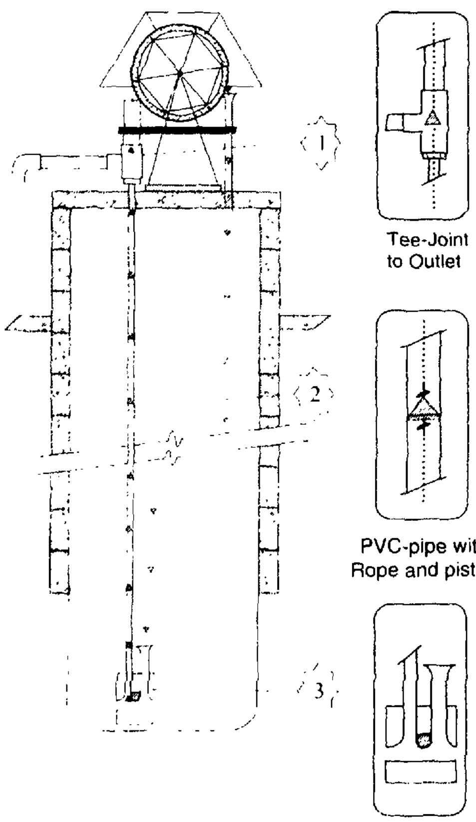
As a result of the International Drinking Water Supply and Sanitation Decade (1981 - 1990), governments and donors began to recognise the importance of handpump-equipped wells and boreholes as an appropriate technology for rural water supply in low-income countries (Arlosoroff *et al.* 1987). Consequently, over the past two decades groundwater has proved the most reliable resource for meeting rural water demand in sub-Saharan Africa (Macdonald & Davies 2000). There are an estimated 250,000 handpumps in Africa, the majority manufactured in and imported from Asia, but it is estimated that less than half of these are currently operational (RWSN 2004). Low levels of sustainability are due to a range of factors including restrictive policies, inappropriate project implementation, lack of willingness to pay for maintenance among user communities, lack of spare parts and technical capacity, and inappropriate technology choice (Harvey & Reed 2004). Technology choice is a key determinant influencing the sustainability of rural water services. Operation and maintenance (O&M) greatly improves when communities are allowed to select a technology which they believe is within their financial, managerial and technical capacity to sustain. The conventional handpump does not always fit this definition and users often prefer simpler technologies (Breslin 2003). Consequently, where communities are not able to choose options for themselves and handpumps are forced upon them, these commonly fall into disrepair, meaning that rural populations are forced to return to unsafe water sources.

doi 10 2166/wh 2006 032

e history of the rope-pump

e rope-pump, also known as the rope-and-washer pump, not a new technology. The basic working principle was rst applied at least two thousand years ago in China lberts 2000). The pump consists of a continuous rope, ith pistons attached to it, which passes over a flywheel, own into the well or borehole, and up through a vertical ipe, the bottom of which is submerged in water. When the ywheel is turned the rope is pulled through the pipe and ach piston traps a column of water inside and raises it to an utlet above the ground surface (Figure 1).

The rope-pump was simultaneously introduced to frica and Latin America during the 1980s as a result of arious water development projects; notable projects took lace in Zimbabwe, where it was developed primarily or micro-scale irrigation (Faulkner & Lambert 1990) and Peru and Bolivia, where the pump was identified as meeting the Village Level Operation and Maintenance (VLOM) criteria (Arlosoroff *et al.* 1987). The VLOM criteria are that the pump is able to be easily maintained by a village caretaker (requiring minimal skills and few tools), manufactured in-country (primarily to ensure the availability of spare parts), robust and reliable under field conditions, and cost effective (Colin 1999). The Peruvian version of the rope-pump was easy to operate, maintain and manufacture locally, and provided a particularly high discharge rate, but was able to operate only at low heads of up to 6 metres (Arlosoroff *et al.* 1987).



igure 1 | Cross-section of rope-pump on hand-dug well

A major evolution in rope-pump technology took place in Nicaragua in 1984 when a small workshop created a rubber washer made by injecting moulds (Alberts *et al.* 1993). This innovation allowed a dramatic increase in the operating head of the pump of up to 40 metres for the standard design. Subsequent adaptation of the design, including the use of smaller diameter pipes and a double crank led to an increased reach depth of 60 to 80 metres (Alberts 2004). This evolution transformed the pump from one used primarily to meet low-lift irrigation needs into a handpump suitable for raising even relatively deep groundwater for domestic use. Despite the development of washers that need to be made by equipped workshops, the technology remained cheap: around US$150 for a complete pump. As a result, the pump spread quickly in Nicaragua which adopted it as a standardised pump in 1996. Consequently, more than 30,000 rope-pumps are currently in use in Nicaragua and provide water to approximately 25% of the total population (Alberts 2004). The rope-pump is a public domain design (Erpf 2002) and consequently there are no restrictions regarding who is able to manufacture it or where it can be manufactured.

The rope-pump was introduced to Ghana in 1999–2000 as the result of a technology transfer programme from Nicaragua supported by the Swiss Agency for Development and Co-operation and the Water and Sanitation Program (WSP) of the World Bank. This programme led to the development of two workshops manufacturing the rope-pump in Tema and Tamale and resulted in the installation of 100 pumps by 2000 (Bombas 2000). Despite some initial problems with the manufacturing quality and implementation strategy (Bombas 2001), the advantages of the pump were recognised by other implementing agencies which led to the establishment of a further manufacturing workshop based in Bolgatanga, Upper East Region. Since its establishment in 2001 this has manufactured and installed more than 120 rope pumps in the region and also provides a repair service to users.

Arguments for and against the rope-pump

It is generally accepted that the rope-pump has a number of advantages over conventional handpumps. These include:

- significantly lower initial cost;
- increased ease of local fabrication and manufacture;
- increased ease and lower cost of maintenance and repair (requiring no specialist skills or equipment);
- lack of reliance on imported specialist components; and
- higher delivery discharge rates.

Arguments against the pump are that it represents a retrogressive step in technology, that rural communities prefer conventional handpumps, and that it is suitable only for low usage (40-60 people per rope-pump rather than 250-300 people per handpump) (Harvey & Skinner 2001). However, the authors have found no documented evidence to support such claims. Undoubtedly, the most common argument against the rope-pump concerns microbiological water quality (Gorter *et al.* 1995). Resistance to the introduction of the rope-pump to sub-Saharan Africa has been based largely on the presumption that the pump is more susceptible to bacteriological contamination than conventional handpumps and that consequently water quality is impaired. The pumping principle applied in the rope-pump by which the rope passes in and out the well is often considered as not entirely satisfactory in terms of protection of the water source compared to conventional handpumps in which the water-contacting parts are enclosed (Bartle 2004). Such arguments have been reiterated by government officials within the Community Water and Sanitation Agency (CWSA) of Ghana (Harvey *et al.* 2002). It should be noted, however, that there are many vested interests involved in the international provision of conventional handpumps, and consequently, individuals or organisations that want to maintain the status quo may seek to find fault with local alternatives such as the rope-pump and exaggerate limitations (Bartle 2004). While previous research has investigated the impact of rope-pumps on water quality in relation to open hand-dug wells and wells fitted with a windlass (Gorter *et al.* 1995), there are no well-documented studies which have compared rope-pumps to conventional handpumps.

AIMS AND OBJECTIVES

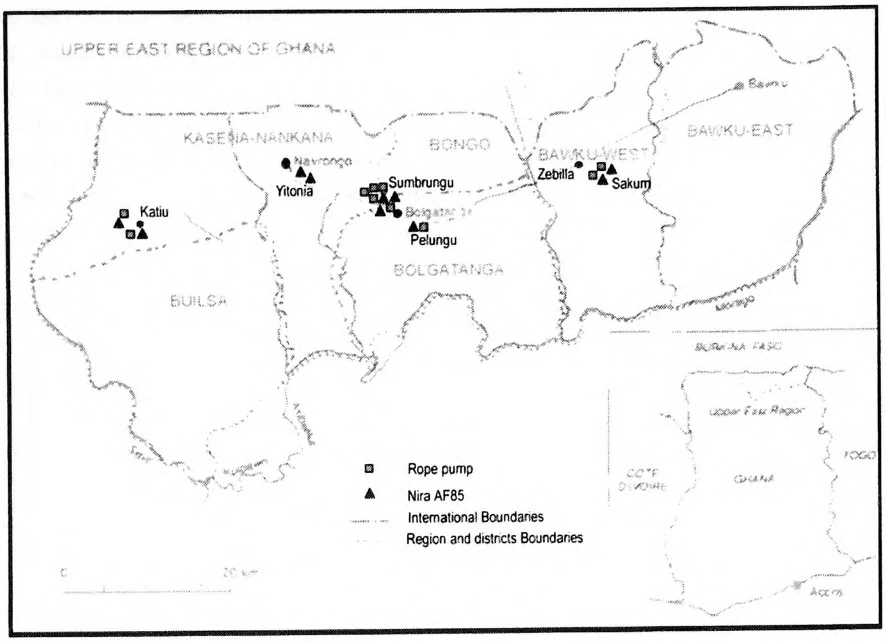
In light of the issues described above the purpose of this study was to undertake an objective comparison of the overall performance of the rope-pump and that of a conventional handpump in Ghana, to determine whether or not the arguments against the rope-pump are valid and to assess the potential of the rope-pump for widened application in sub-Saharan Africa.

METHODOLOGY

Selection of wells and pumps

The key criteria for identifying an appropriate project area were that rope-pumps and conventional handpumps should be installed on the same type of water sources, in identical hydrogeological and climatic conditions, and subject to identical or near-identical sanitary pollution risk and usage loads. Based on these criteria the Upper East region of Ghana was selected (Figure 2).

The first rope-pumps installed in the Upper East region were done so under the responsibility of CWSA, which is reportedly undertaking field tests on them but is yet to release any findings (Babisma 2004). Currently, the main promoter of the rope-pump in the region is Rural Aid, a local Non-Governmental Organisation (NGO) financed predominantly by the international NGO Wateraid. The water development programme of Rural Aid over the past decade has focused on the provision of improved hand-dug wells. The initial plan was to equip all wells with the Nira AF85 handpump, one of the four nationally standardised conventional handpumps permitted for use in Ghana. Each community in the programme was expected to make a financial contribution of 150,000 cedis (US$15) and a substantial in-kind contribution to the cost of the water



igure 2 | Map of pump locations

upply. The remainder of all costs was to be met by Rural Aid, the cost of a single Nira AF85 handpump being approximately US$700 (Nampusuor & Mathisen 2000). Two thousand wells had been provided by the end of 2003, but one thousand two hundred of these were still not equipped with a handpump because Rural Aid was unable to afford the price of the Nira. Consequently, the NGO decided to purchase rope-pumps, at a cost of approximately US$150 per pump, and to install these on some of the remaining hand-dug wells, while continuing to install a reduced number of Nira pumps.

This situation produced an ideal environment in which to undertake a comparative performance analysis of the two pumps. Since both pump types are predominantly used for low-lift applications on hand-dug wells it was deemed appropriate to select the Nira pump as a representative conventional handpump alternative to the rope-pump. Twenty hand-dug shallow wells were selected for the study, ten equipped with Nira handpumps and ten equipped with rope-pumps. Each rope-pump well was selected as close as possible to a corresponding Nira pump well to ensure similar hydrogeological settings and to maximise comparability potential. The wells ranged in depth from 6.1 metres to 12.1 metres (with no significant variation between the two types of pumps) and all had been fully lined by Rural Aid technicians. The hydrogeology of the study area is typified by a layer of weathered fractured sandstone of an average depth of 40 metres (ODI 1998). The age of the pumps varied from 1 to 5 years and sanitary surveys were conducted to assess the quality and state of repair of the well constructions to ensure that any degradation was considered.

User interviews

User interviews were conducted in each community following a standard format. The interviews were designed to collect information about the construction of the well, the acceptance of the pump by the community, the uses of water, the number of people using the pump, the maintenance system and the costs of installation, operation and maintenance.

Sanitary inspections

Sanitary inspections are necessary to support microbiological water quality assessment by identifying potential pollution sources and contaminant pathways to provide an overview of the status of risk of the water source to contamination (WHO 1997; Howard 2002). In order to conduct assessments, sanitary inspection forms were developed in conjunction with Rural Aid staff after visiting pumps of both types. These were based on those developed by WHO (1997) but modified to the specific settings encountered in northern Ghana. One sanitary inspection was conducted for each well site in the study using a standard format (as shown in Table 1).

The equal weighting applied in this method is not entirely satisfactory as some factors may present greater risks than others but can be used to obtain an overall approximation of water source pollution risk (Lloyd & Helmer 1991).

Table 1 | Sanitary inspection questions

Sanitary inspection questions
1. Is there a latrine within 10 m of the well?
2. Is the nearest latrine on higher ground than the well?
3. Is there any other source of pollution within 10 m of the well?
4. Is the drainage poor, causing stagnant water within 2 m of the well apron?
5. Is the drainage channel cracked, broken or in need of cleaning?
6. Is the apron less than 1 m in radius around the top of the well?
7. Is the fence around the pump missing or faulty?
8. Does spilt water collect in the apron area?
9. Are there cracks in the apron which could permit water to enter the well?
10. Is there stagnant water on the wellhead cover?
11. Are there cracks in the wellhead cover?
12. Is the hatch not, or badly, sealed?
13. Are the two pipes not or badly sealed in the concrete cover? (rope-pump) OR is the seal of the shaft loose? (handpump)
14. Is there water going back into the well through the down pipe? (rope-pump) OR are the two base gaskets damaged or badly placed? (handpump)

Score Yes-1, No-0, Overall 14 worst, 0 best

Water quality analysis

The main water quality parameter analysed was presumptive counts of thermotolerant coliforms, chosen as an acceptable alternative to *E. coli* (Dufour *et al.* 2003; Bartram & Ballance 1996) because of time and resource constraints. Analysis was conducted using the membrane filtration technique as employed by the Oxfam-Delagua water testing kit. The samples were cooled and filtered immediately after sampling and were incubated for 18 hours at 44° Celsius. A minimum of three water quality samples was analysed for each well collected on three separate occasions. Additional parameters analysed on site were turbidity, pH, colour and temperature.

Since previous research has indicated a significant relationship between microbiological contamination of shallow groundwater and rainfall, especially depth of rainfall in the previous 48 hours, (Howard *et al.* 2003) it was important that this variable was considered when taking samples for analysis. Consequently, equal numbers of samples from adjacent rope-pump wells and handpump wells were collected on each day of sampling.

Cost assessments

In order to determine the initial and ongoing costs, interviews were conducted with communities, private sector suppliers and sector professionals. It was relatively easy to determine initial capital costs, primarily on the basis of information provided by NGOs. Determining ongoing O&M costs was considerably more difficult, however. Responses from pump-user interviews were highly variable and it was not possible to compute realistic maintenance costs on the basis of these alone. Consequently, it was necessary to collate sales data from spare parts suppliers and service data from repair and maintenance service providers, to determine the average cost of O&M for each ump type. Data from previous studies were also used to ack-up these findings.

echnical performance assessments

imple technical assessments were conducted for each ump visited to determine the average maximum pumping elivery head (in metres) and the average maximum flow ate (in litres per minute) for each pump type. The results of hese assessments were backed up with available technical lata from manufacturers and impartial assessors. The naximum pumping head is an important indicator since it ndicates the versatility of the pump for different pumping ieeds required for different groundwater depths. The flow ate is also important since it has a direct impact on the ength of waiting times at the pump and consequently, the iumber of users that can be served.

omparative Performance Analysis method

The Comparative Performance Analysis (CPA) method itilised in this study was adapted from the basic principles idopted in multi-attribute utility-measurement for social decision making (Edwards 1976). The purpose of this method was to compare the performance of the two pumps on the basis of the following variable factors:

- Capital costs;
- Impact on microbiological water quality;
- Maintenance costs;
- Maximum pumping head;
- Flow rate; and
- Impact on turbidity.

Additional variables such as depth of wells, number of users, sanitary conditions, hydrogeological environment and rainfall were identical or near-identical for both pump types, and hence were excluded from the CPA method. A range of NGOs and communities was asked to rank the range of variables in terms of their relative importance. On the basis of the average results of this ranking exercise the importance of the different factors was then weighted. The least important parameter received a score of 1, then each factor was attributed a score corresponding to its relative importance ratio to the least important parameter. The weight of each factor was then computed as follows:

W_i = score for i^{th} factor / sum of all factor scores

Where:

W_i = importance weight for the i^{th} factor.

A measure of location of each type of pump for each factor, on a scale from 0 to 100 was then used: 0 being the score for the worst plausible value and 100 the best plausible value. The location of each type of pump on the scale was then computed as follows:

$$S_{ij} = \frac{|worst_i - value_{ij}|}{|best_i - worst_i|}$$

Where:

S_{ij} = scaled position of the j^{th} entity on i^{th} factor.
$Best_i$ = best plausible value of i^{th} factor
$Worst_i$ = worst plausible value of i^{th} factor
$Value_{ij}$ = value of j^{th} entity on i^{th} factor

Finally, the overall score of each pump was then computed as follows:

$$S_j = \sum_{i=1}^{n} (W_i)(S_{ij})$$

Where:

S_j = overall evaluation score for the j^{th} alternative (pump)
J = number of alternatives (2)
W_i = importance weight for i^{th} factor (or parameter)
n = number of factors of value (6)
S_{ij} = scaled position of the j^{th} entity on i^{th} factor.

RESULTS AND DISCUSSION

User issues

The number of users per pump was estimated by each of the communities visited in the study, and was found to vary from 125 to 300, with an average of 196 people per pump. An estimation of the average water consumption was determined as 35 litres per person per day. There was no significant difference between the two pump types for either variable, disproving the assumption that the rope-pump can serve only family groups rather than entire rural communities.

In terms of user perceptions, again there was no measurable difference between the two pumps. The Nira and the rope-pump were each perceived as an advanced water supply technology compared to river water or the open wells that communities had been using previously. It was recognised that the rope-pump required more regular maintenance and repair than the Nira pump, but since repairs could be undertaken relatively quickly and cheaply this was not perceived as a major constraint. No particular preference between the two pump types was expressed by any community survey respondent.

Sanitary inspections

The use of sanitary inspection forms involved a significant degree of informed subjectivity by the assessor. For example, it was necessary to determine what size of cracks in the well cover should be considered a pollution risk and what amount of water on the well head cover constitutes a risk. However, all sanitary inspections were conducted by the same assessor to ensure consistency. The scores of the sanitary inspections ranged from 7 to 10 on a scale of 0 to14, and the average sanitary scores for both pump types were identical (Table 2).

Water quality

No major differences were encountered between the two types of pump concerning the measured physical water quality parameters, with the exception of turbidity. Turbidity varied significantly according to geographical area (linked to local geology) but also varied significantly in relation to pump type. The average turbidity of water delivered by rope-pumps was 13 NTU while an average turbidity of 29 NTU was recorded for the water delivered by Nira pumps. One possible explanation for this difference is that the discontinuous reciprocating action of the Nira causes more movement in the well water than the smooth continuous movement of the rope, thus increasing the turbidity of the water by the pump stirring up sediments settled at the bottom of the well.

Presumptive counts of thermotolerant coliforms recorded for each pump type are summarised in Figures 3 and 4. The mean count for the rope-pumps

Table 2 | Sanitary inspection scores

Sanitary inspection scores

Community	District	Pump type	Sanitary score
Atiabisi	Bolgatanga	Rope-pump	9
Aguridone	Bolgatanga		8
Azimsun	Bolgatanga		8
Aniabisi	Bolgatanga		8
A. Asaka	Bolgatanga		10
Baandaborg	Bolgatanga		9
Natinga	Bawku-West		10
Gandare	Bawku-West		10
Adunia	Kasena-Nankana		8
Muslim	Kasena-Nankana		7
Total			87
Sokabisi	Bolgatanga	Handpump	7
Atoobisi A.	Bolgatanga		9
Asapombisi	Bolgatanga		7
Pel. Nairi	Bolgatanga		10
Gundago	Bawku-West		9
Lanaga	Bawku-West		10
Asason	Kasena-Nankana		9
Afania	Kasena-Nankana		9
P. Talua	Kasena-Nankana		8
P. Aduntra	Kasena-Nankana		9
Total			87

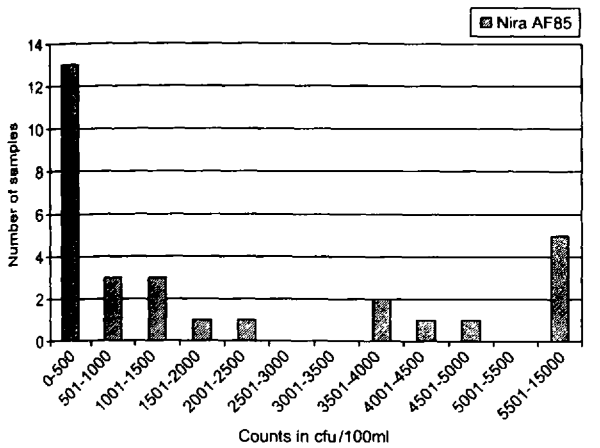


Figure 3 | Summary of presumptive thermotolerant coliform counts for Nira handpumps

was 2015 cfu/100 ml and the mean count for the Nira AF85 was 2474 cfu/100 ml, indicating little difference between the two pumps. In order to test this relationship further the log median value of the counts was used as an outcome measure for each pump type (Howard *et al.* 2003; Gorter *et al.* 1995; Helsel & Hirsch 1992). The distribution of the log median values for each type of pump was tested for normality using the probability plot correlation coefficient (PPCC) test, which indicated that at least one set of data was not distributed following a normal distribution. The comparison between the two sets of data was therefore conducted using a non-parametric test, the Wilcoxon's rank-sum test because of its strength in comparison (Helsel & Hirsch 1992); the null hypothesis being "the presumptive thermotolerant coliform counts for the rope pumps and for the Nira pumps are similar" and the alternate hypothesis being "the presumptive thermotolerant coliform counts for the rope pump and for the Nira pump are significantly different.". The test was conducted using the median of the log coliform counts as an outcome measure for each pump type. The p-value obtained by the test was $p = 0.65$, which indicates that the null hypothesis should be accepted. This confirmed that there was no significant difference between the two pump types in terms of microbiological water quality.

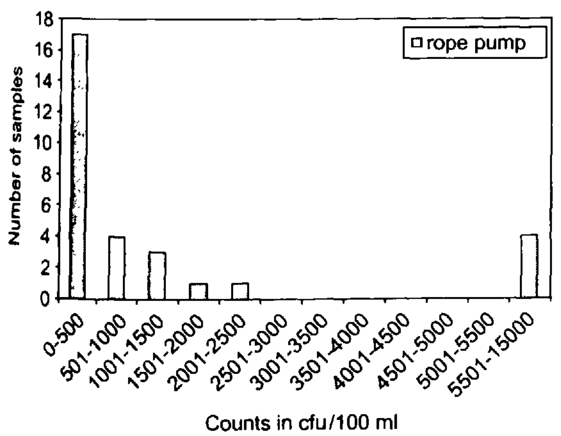


Figure 4 | Summary of presumptive thermotolerant coliform counts for rope-pumps

Costs

Capital costs and O&M costs for 1036 Nira pumps in the Upper Regions of Ghana had been previously calculated by Nampusuor & Mathisen (2000), over a period of six years from 1996 to 2001 inclusive. The results of that study indicated a capital cost of US$700 for a Nira pump on a well of 12 metres depth, and average maintenance costs of approximately US$89 per annum including the replacement of the pump after 15 years without any discount rate.

The capital cost of a Ghanaian rope-pump made by Jenamise Enterprise is approximately 1,500,000 cedis (US$168), although there has been no detailed study of maintenance costs in Ghana. One study led by the WSP (2001) in Nicaragua gives maintenance costs of around $US5 per annum for the rope-pump. However, this does not consider the depreciation of the pump and subsequent replacement cost. If a moderate lifespan of five years is assumed for the rope-pump then US$40 per annum can be used an indicative value of maintenance costs which incorporates these considerations.

Technical performance

The pumps assessed in this study were installed on hand-dug wells up to a maximum depth of approximately 12 m and consequently it was not possible to assess them at greater depths. However, the maximum pumping heads recorded for the Nira pump and the rope-pump, as specified by the respective manufacturers, are 12 m and 40 m respectively. These figures are backed-up by independent assessments (Arlosoroff *et al.* 1987; Brikké 2003). It should be noted that for deeper installations (above 15 m) the rope-pump has to be installed in a drilled borehole rather than a hand-dug well. Nonetheless, this indicates that the rope-pump is significantly more versatile than the Nira as a low-lift domestic water supply pump. This is crucially important in the sub-Saharan Africa context where approximately 40% of the land area is underlain by Precambrian basement rocks, typified by a water-bearing weathered zone of 10–30 m depth, and 220 million rural dwellers live in these areas (MacDonald *et al.* 2002).

Average maximum flow rates for a 10 m delivery head were recorded as 28 l/min for the Nira pump and 41 l/min for the rope-pump. This indicates that the rope-pump has a comparative advantage, since it is able to deliver water at approximately 1.5 times the rate of the Nira.

CPA results

The six variable factors identified were ranked by a selection of NGOs and communities which allocated a score of 10 to the perceived most important factor. All other factors were then allocated scores according to their perceived importance relative to the most important factor. On the basis of this the average scores were compiled and an importance weight determined for each (see Table 3). This showed that capital cost was the most important factor closely followed by the impact on microbiological water quality. Maintenance costs and maximum pumping head also scored

Table 3 | Importance weightings

Factor	Scores	Importance weight, W_i
Capital costs	10	25.3
Impact on microbiological water quality	9	22.8
Maintenance costs	8.5	21.5
Maximum pumping head	7	17.7
Flow rate	4	10.1
Impact on turbidity	1	2.6
Total	39.5	100

Table 4 | Scaled positions for each factor for both pump types

			Handpump		Rope pump	
Factor	**Worst plausible value**	**Best plausible value**	**Value**	**Score S_{ij}**	**Value**	**Score S_{ij}**
Capital costs (US$)	$700 (value of the most expensive hand pump)	$10 (price of a rope and bucket system)	$700	0	$168	0.77
Impact on microbiological water quality	16000 cfu/100 ml	0 cfu/100 ml	2474 cfu/100 ml	0.85	2015 cfu/100 ml	0.87
Maintenance costs (US$/annum)	$90	$1 (price of a rope and bucket system)	$89	0.01	$40	0.56
Maximum pumping head	7 m (suction pump)	100 m (deep well piston pump)	12 m	0.05	40 m	0.36
Flow rate at 10 m head	15 litres/ min (rope and bucket)*	50 litres/min	28 l/min	0.37	41 l/min	0.74
Impact on turbidity	100 NTU	0 NTU	29NTU	0.71	13NTU	0.87

* Brikke and Bredero 2003

Table 5 | Overall evaluation scores

	Score, S_{ij}			Weighted score, W_iS_{ij}	
Factor	NIRA	Rope	Importance weight, W_i	NIRA	Rope
Capital costs	0	0.80	25.3	0	19.5
Impact on microbiological water quality	0.85	0.87	22.8	19.4	19.8
Maintenance costs	0.01	0.96	21.5	0.22	12.0
Maximum pumping head	0.05	0.36	17.7	0.89	6.37
Flow rate	0.37	0.74	10.1	3.74	7.47
Impact on turbidity	0.71	0.87	2.6	1.85	2.26
Total, S_j				26.1	67.4

relatively highly, while flow rate and impact on turbidity were deemed less important.

The worst and best plausible values for each assessment factor were then determined based on field evidence and compared to the mean values for each factor for each pump type (see Table 4). Consequently, the scaled positions for each factor for each pump type on a scale from 0 to 100 were determined in relation to the worst and best plausible values.

The final stage of CPA was to determine the weighted scores for each factor for both pump types and to sum these to determine the overall evaluation score for each pump type (see Table 5). This final overall scores obtained were 26.1 for the Nira pump and 67.4 for the rope-pump (on a scale of 0 to 100), giving a rope-pump score of approximately two and a half times that for the Nira pump. The results also indicate that the rope-pump outperforms the Nira pump for all six assessment parameters.

CONCLUSIONS

The Comparative Performance Analysis approach demonstrates an objective assessment method to compare the performance of two or more pumping technologies in relation to key assessment criteria. The process adopts a participative approach to prioritising and comparing the importance of different assessment parameters.

The CPA results indicate that the rope-pump demonstrates increased performance for all of the assessment parameters in comparison to a conventional low-lift handpump, the Nira AF85. The rope-pump is significantly cheaper in terms of both capital costs and maintenance costs, and delivers a pumping head considerably higher than that of the Nira pump. Most importantly, perhaps, it has a near identical impact on microbiological water quality despite contrary negative perceptions. It is recognised that the Nira pump is significantly more expensive than other direct action handpumps such as the Tara and Malda pumps, as well as conventional low-lift handpumps such as the Afridev. This may exaggerate the relative advantages of the rope-pump as compared to all conventional handpumps, but this comparison was limited by the need to identify an environment in which rope-pumps and conventional pumps were operating in near identical conditions. Although the difference between the two pump types would probably have been less dramatic if a less expensive conventional pump had been used in the comparison, the overall similarities between the conventional handpumps available indicate that the rope-pump would still have come out top in the CPA by a significant margin.

The financial and technical advantages can be coupled with the fact that the rope-pumps are manufactured locally. Therefore, in terms of economic viability and reliability, benefits for the users, and sustainability, it can be argued that the rope-pump should be actively promoted as a low-lift pump (especially on hand-dug well installations) and, as a first step towards its broader dissemination, accepted as a standardised pump by the Ghanaian Government. Based on the findings of the CPA study in Ghana the case for the rope-pump in Africa would indeed appear to be a strong one.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the staff of WaterAid Ghana and Rural Aid Ghana for the extensive assistance provided for conducting field assessments.

REFERENCES

Alberts, H. 2000 Community rope pumps in Nicaragua; a private sector approach. In Paper presented at *Clean water delivery, Village Power 2000*. December 2000. International Institute for Sustainable Development, Winnipeg, Canada.

Alberts, H. 2004 The rope pump: an example of technology transfer. *Waterlines* **22**(3), 22-25.

Alberts, H., Meza, R., Solis, D. & Rodriguez, M. 1993 How the rope pump won in Nicaragua. *Waterlines* **12**(2), 3-5.

Arlosoroff, S., Tschannerl, G., Grey, D., Journey, W., Karp, A., Langeneffer, O. & Roche, R. 1987 *Community water supply: The handpump option*. The World Bank, Washington DC.

Babisma, E. 2004 CWSA engineer in Bolgatanga personal communication (26 August 2004).

Bartle, P. 2004 *Consider the Rope Pump: Assisting communities to do things for themselves* Training Handout (http //www scn org/cmp/modules/wat-ro htm, accessed March 2005).

Bartram, J. & Ballance, R. 1996 *Water Quality Monitoring*. E&FN Spon, London.

Bombas 2000 *Support Technology Transfer of rope pump - Nicaragua/Ghana - Final Report to the Water and Sanitation Program (WSP) - period: November 1999-June 2000*. Technology Transfer Division Bombas de Mecate S.A. Managua.

Bombas 2001 *Support Technology Transfer of rope pump - rope pump takes root in Ghana - Report on follow-up and fact-finding mission - Ghana 11th to 23rd November 2001*. Technology Transfer Division Bombas de Mecate S.A. Managua.

Breslin, E. D. 2003 The Demand-Responsive Approach in Mozambique: Why choice of technology matters. In *Waterfront* Issue 16. Fall 2003, UNICEF, New York.

Brikké, F. & Bredero, M. 2003 *Linking technology choice with operation and maintenance in the context of community water supply and sanitation - A reference document for planners and project staff*. WHO, IRC water and sanitation centre, Geneva.

Colin, J. 1999 *Lessons learned from village level operation and maintenance*. WELL Study Task 162, WELL, WEDC, Loughborough University, UK.

Dufour, A., Snozzi, M., Koster, W., Bartram, J., Ronchi, E. & Fewtrell, L. 2003 *Assessing Microbial Safety of Drinking Water: Improving approaches and methods*. WHO, TJ International Ltd, Padstow, UK.

Edwards, W. 1976 *How to Use Multi-Attribute Utility Measurement for Social Decision Making*. SSRI Research Rep. 76-3, Social Science Research Institute, University of Southern California, Los Angeles, USA.

Erpf, K. 2002 *Technology Selection - and Buyers' Guide for Public Domain Handpumps for Drinking Water*. HTN/SKAT, St. Gallen, Switzerland.

Faulkner, R. D. & Lambert, R. 1990 The Rope-Washer Pump for Micro-Scale Irrigation. *Proceedings of the Institution of Civil Engineers* **88**(1), 81-90.

Gorter, A. C., Alberts, J. H., Gago, J. F. & Sandiford, P. 1995 A randomized trial of the impact of rope pumps on water quality. *Journal of Tropical Medicine and Hygiene* **98**, 247-255.

Harvey, P. A. & Skinner, B. H. 2001 *Sustainable Handpump Projects in Africa: Report on Workshop, Lusaka, Zambia, 24 August 2001*. WEDC, Loughborough University, UK.

Harvey, P. A., Jawara, D. & Reed, R. A. 2002 *Sustainable Handpump Projects in Africa: Report on Fieldwork in Ghana* WEDC, Loughborough University, UK.

Harvey, P A. & Reed, R. A. 2004 *Rural Water Supply in Africa: Building blocks for sustainability*. WEDC, Loughborough University, UK.

Helsel, D. R. & Hirsch, R. M. 1992 *Statistical methods in water resources*. Elsevier Science, Amsterdam, Holland.

Howard, G., Pedley, S., Barret, M., Nalubega, M. & Johal, K. 2003 Risk factors contributing to microbiological contamination of shallow groundwater in Kampala. *Uganda. Water Research* **37**, 3421-3429

Howard, A. G. 2002 *Water Supply Surveillance: A reference manual*. WEDC, Loughborough University, UK.

Lloyd, B. & Helmer, R. 1991 *Surveillance of Drinking Water Quality in Rural Areas* Longman Scientific & Technical, Essex, England

Macdonald, A. M. & Davies, J. 2000 *A Brief Review of Groundwater for Rural Water Supply in Sub-Saharan Africa Technical Report WC/00/33, Overseas Geology Series*. British Geological Survey, UK

MacDonald, A. M., Davies, J & Dochartaigh, B. 2002 *Simple methods for assessing groundwater resources in low permeability areas of Africa. Commissioned Report CR/01/168N*. Britich Geological Survey, UK ampusuor, R. & Mathisen, S. 2000 *Report on the performance of Afridev and Nira handpumps on the Upper Regions Community Water Project (COWAP) Ghana*. COWAP Field Paper 27, Report for the GWSC/CIDA, Community Water project Upper Regions, Ghana.

DI 1998 *Rethinking Natural Resource Degradation in Semi-Arid Sub-Saharan Africa: The case of semi-arid Ghana*. Faculty of Agriculture, University for Development Studies, Tamale, Ghana, in collaboration with the Overseas Development Institute, London.

RWSN 2004 *The Handpump*. Network for Cost-Effective Technologies in Water Supply and Sanitation, SKAT, St. Gallen, Switzerland.

WHO 1997 *Guidelines for Drinking-Water Quality, Second Edition, Volume 3: Surveillance and Control of Community Supplies*. World Health Organization, Geneva, Switzerland.

WSP 2001 *The rope pump: Private Sector Technology Transfer From Nicaragua to Ghana - Developing Private Sector Supply Chains to Deliver Rural Water Technology*. Water and Sanitation Program, Washington DC.

Available online May 2006

6. ENVIRONMENT

30th WEDC International Conference, Vientiane, Lao PDR, 2004

PEOPLE-CENTRED APPROACHES TO WATER AND ENVIRONMENTAL SANITATION

Borehole Sustainability in Rural Africa: An analysis of routine field data

P.A. Harvey, UK

Handpump-equipped boreholes are one of the most common water supply technologies adopted in rural Africa, but often demonstrate low levels of sustainability. In addition to operational problems with the pump, the borehole itself may cease to provide adequate quantities of safe drinking water only a short time after construction. This can have a significant negative impact on poor rural communities, particularly in the dry season when alternative water sources are scarce. A study of 302 boreholes in Ghana aimed to investigate rapid-onset borehole failure in relation to field data typically available following drilling and development. The study showed that the likelihood of borehole failure increased by a factor of six when drilling occurred during the wet season, and discovered a strong correlation between monthly precipitation and respective failure rates for boreholes drilled in each month. The potential for borehole failure also increased significantly when the initial yield was below the guideline value of 10 l/min. There was no indication, however, that a higher guideline value would be a cost-effective measure to reduce failure rates.

Introduction

Groundwater provides potable water to an estimated 1.5 billion people worldwide daily (DFID, 2001) and has proved the most reliable resource for meeting rural water demand in sub-Saharan Africa (MacDonald & Davies, 2002). Boreholes equipped with handpumps are a common technology adopted by poor rural communities, and there are currently approximately 250,000 handpumps in Africa (HTN, 2003). In 1994 it was estimated that 40-50% of handpumps in sub-Saharan Africa were not working (Diwi Consult & BIDR, 1994). This is backed up by more recent data from Uganda (DWD, 2002) and South Africa (Hazelton, 2000), which indicate similar operational failure rates. An evaluation in Mali in 1997 found 90% of pumps inoperable just one year after installation (World Bank, 1997). The primary reason for these high failure rates, and hence low sustainability, is insufficient attention to operation and maintenance of the pump (Harvey & Reed, 2004). This borehole itself, however, is sometimes the source of the problem. This study aims to investigate cases in which it is the borehole, rather than the pump, that has failed.

The term borehole failure as used here refers to a situation in which a borehole which is deemed 'successful' at the time of drilling subsequently fails to deliver a sufficient yield of safe water throughout the year. This does not necessarily refer to the structural failure of the borehole itself, but may occur due to a number of reasons, including depletion of groundwater levels in weathered aquifers and insufficient recharge of fractured aquifers resulting in dry boreholes. Failure may also occur as a result of: a reduction in yield; plugging of the formation around the well screen by fine particles; sand pumping due to siltation, incrustation or corrosion of casing and screens; and structural collapse of casing and screens, often as a result of corrosion due to low-pH (acidic) waters (Driscoll, 1995). Over abstraction of water from the aquifer, and the ingress of pollutants may also result in borehole failure. Boreholes which are ephemeral in nature due to seasonal fluctuations in yield and water level, are also classified as failures, since although water was available directly following drilling it is not available on a continuous basis.

Most rural water supply boreholes in Africa are drilled by private contractors or Non-Governmental Organisations (NGOs). In general, operating staff have limited technical knowledge and equipment, and often lack basic knowledge regarding the hydrogeological conditions within which they are working. There is also often a lack of effective Government regulation or supervision. Consequently, the quality of workmanship varies considerably, as does the ability to identify, predict and mitigate against possible borehole failure.

This paper is based on research conducted in Ghana in a project area covering parts of Eastern, Ashanti and Brong Ahafo regions, which for the purposes of this study will be known as the Greater Afram Plains (GAP). The study focused on boreholes drilled by World Vision, Ghana between October 1995 and March 2003 under phase III of the Ghana Rural Water Project (GRWP). The research considered 'rapid-onset' borehole failure, or boreholes that fail within seven years of drilling. The focus on boreholes that fail within a few years of construction was based on the crucial need to minimise such occurrences in the interests of efficiency and effectiveness. The study does not preclude the need to address longer-term borehole failure, and findings are likely to remain relevant to both categories.

Rapid-onset borehole failure may have a significant negative impact on members of the user community, who have contributed financially to the construction of the water point and are often trained to ameliorate mechanical problems with the handpump, but have no capacity to resolve borehole problems. Negative effects are felt most strongly during the dry season when alternative water sources are most scarce, and yet, due to lowering groundwater levels, it is at these times that boreholes are most likely to dry up.

Research objective

The study aimed to analyse data routinely collected during borehole drilling and development in order to determine the relationship, if any, between each data variable and subsequent failure of boreholes, and so determine whether these data can be used to predict or mitigate against failure. The focus was on practical field data, as collected and recorded by drilling teams, rather than specialist hydrogeological monitoring data. The rationale behind the selection of these variables was based simply on the likelihood of availability of such data. This data links with the overall objective of identifying existing field practice(s) that may have a detrimental affect on borehole sustainability, in order to recommend any appropriate adjustments to field procedures.

Borehole 'success'

One of the main problems faced in addressing borehole failure is that there is often no clear definition of borehole success at the drilling stage. According to senior staff of GRWP a borehole should only have been deemed successful if at the time of drilling the measured 'yield' was at least 10 litres per minute (l/min). Borehole 'yield' can be loosely defined as the maximum rate at which a borehole can be pumped without lowering the water level in the borehole below the pump intake. It is important to note that this is not the same as the 'safe' or 'sustainable' yield of an aquifer which is an essentially subjective concept (Foster *et al.*, 2000).

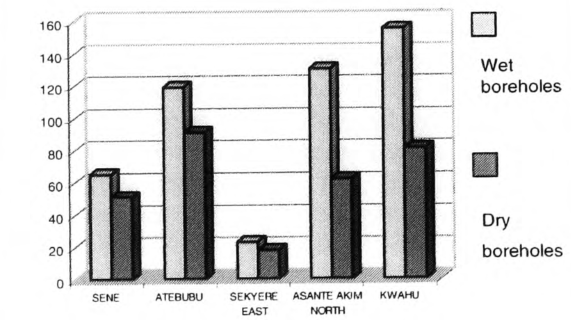
The borehole yields recorded by GRWP drilling teams were estimated during a 6-hour constant rate pumping test. The yield was determined by the maximum pumping rate reached within the permitted drawdown for the borehole and handpump. Despite the guideline figure of 10 l/min, in examining borehole records it was noted that in some cases boreholes with measured yields of as low as 7 l/min were classed as 'successful' and were subsequently equipped with handpumps. Consequently all drilled boreholes were classified as either successful or unsuccessful, or 'wet' or 'dry', largely at the discretion of the field supervisor. Where there was no water in the borehole at all, or where there was a very high yield, this task became easy.

The hydrogeology of the GAP is typified by Palaeozoic consolidated sedimentary rocks, locally referred to as the Voltaian Formation. These consist mainly of sandstones, shales, arkoses, mudstones, laterites and limestones (Gyau-Boakye & Dapaah-Siakwan, 1999). The Voltaian formation has little or no primary porosity, hence groundwater occurrence is associated with the development of secondary porosity resulting from jointing, shearing, fracturing and weathering. This has consequently given rise to two main types of aquifer, the weathered zone and the fractured zone aquifers, both of which are found in the GAP. There is no clear demarcation between aquifer types, but where water is held in fracture zones, borehole siting is, in general, a significantly more arduous task than where it is contained in the weathered zone (World Vision, 2003).

All study boreholes were sited by GRWP hydrogeologists. Geophysical surveying methods (electromagnetic EM34 and resistivity) were used for siting in approximately one third of cases. The overall ratio of wet-to-dry boreholes for the five selected districts of the GAP was as follows:

- Wet boreholes drilled: 492
- Dry boreholes drilled: 303
- Overall success rate: 62%

A point of interest is that the overall drilling success rate for Phase I and Phase II of GRWP (1985-1995) in the GAP was 55%, while this rose to 62% for Phase III with the introduction of geophysics for the more difficult sites. Drilling success rates are broken down by district in Figure 1. As can be seen from the graph the success rate in each of the five districts varied from 56% to 68%. These success rates will be revisited later in this paper in relation to subsequent borehole failures.



Success: 56% 57% 56% 68% 66%

Figure 1. Boreholes drilled in the GAP (1995-2003)
Source: World Vision, Ghana, 2003

Since the GRWP drilling programme continued throughout the year, the success rates quoted do not necessarily indicate that these wells remained wet all year round. Several boreholes observed were drilled during the wet season and were reported to dry up in the dry season. This led to water being available for only 6-8 months of the year in some cases. Such situations are classed as examples of where boreholes have 'failed' and are included in this study.

Borehole 'failure'

For the purposes of this study borehole failure is defined as when a borehole, which was recorded as successful, or 'wet' immediately after drilling, subsequently fails to deliver a sufficient yield of safe water throughout the year. A handpump borehole can be defined as successful if it is able to supply water to a population of 250 people, requiring 25 litres per person per day, where pumping takes place over a 12 hour period (MacDonald *et al.*, 2002). Assuming constant operation of the pump over the 12-hour period this gives a required yield of 8.7 l/min. In order to allow for gaps in pumping and water spillage sufficient yield is defined as 10 l/min. However, for a design population of 250 this still equates to 10.4 hours of pumping which may not be very convenient for users. The value of 10 l/min is therefore set as a **minimum** guideline value only. Wurzel (2001) suggests that the absolute maximum delivery rate of a handpump is 1 cubic metre per hour (m3/hr), or 16.7 l/min, though in reality this is rarely achieved.

It is important to note that a water supply borehole may also be deemed to have 'failed' if the water provided by it is unsafe for human consumption. The GRWP Water Quality unit conducted an analysis of the following inorganic (chemical) parameters for each borehole: Na, K, Ca, Mg, As, Fe, Mn, Si (SiO_2), HCO_3, Cl, F, NO_3, PO_4 and NO_2. In total, 306 wells were sampled and analysed in the GAP by March 2003; 94% of those sampled in the GAP satisfied the WHO Drinking Water Guideline values and Ghana Standards Board (GSB) standards for all chemical parameters evaluated. The only parameter of public health concern detected was Fluoride. Fluoride concentrations above the WHO guideline figure and the maximum contaminant limit (mcl) of 1.5mg/l were detected in six boreholes (3%). Since excessive Fluoride can lead to the development of dental and skeletal fluorosis (WHO, 1997) these boreholes were also deemed to have failed. Since the field practices of drilling and development teams cannot have a significant influence on Fluoride concentration, this study focused only on those boreholes that had failed physically, i.e. in which there was insufficient quantity of water.

Borehole or handpump?

The first step in assessing borehole failure is to determine the frequency of the problem in relation to other operational failures. A survey of 492 handpump-equipped boreholes in the GAP was conducted in which all water points were visited towards the beginning of the wet season (March 2003) and those that failed to deliver adequate water were assessed to determine whether this was due to mechanical failure of the pump or failure of the borehole. This survey indicated that 64 point sources and hence 13% of all water points had failed. This is a relatively low failure rate for a project which has been running for seven years (in comparison to the figures quoted in the introduction) and is testament to the committed ongoing support provided to communities by World Vision Ghana. The water point survey produced the following results:

- Total number of water points visited: 492
- Total number of failed handpumps: 42
- Handpump failure rate: 8.5%
- Total number of failed boreholes: 22
- Borehole failure rate: **4.5%**

The results indicate that the failure rate for handpumps was almost double that for boreholes. However, where a handpump had failed it was not possible to determine whether or not the borehole had also failed, which means that the proportion of failed boreholes may have been higher than that indicated. This means that in the case of GAP rapid-onset borehole failure accounted for **at least** one-third of all water point failures, which makes it a significant problem.

Variables investigated

In order to determine the possible causes of borehole failure, the following variables were analysed for each borehole. These were:

- Initial recorded yield of borehole;
- Borehole depth in relation to dynamic water level;
- Depth of cylinder below dynamic water level; and
- Season during which drilling took place.

These criteria were based on existing field data, to discover whether there are 'hidden' clues, which can help determine the possible causes of borehole failure. Due to incomplete construction and assessment data for some boreholes, the total sample size was reduced to 302.

In addition to the above variables, the borehole failure rate in each district was compared to the respective borehole siting success rate to determine if there was any correlation between the two factors. Since boreholes in the study area were drilled over a seven-year period the age of failed boreholes was also analysed to determine the percentage of boreholes drilled each year that subsequently failed. This was used to determine whether there was an overall trend in increasing failure with age, as would be expected.

The quality of borehole installation (Photograph 1) was not considered as a variable since all boreholes were drilled, developed and constructed following consistent practice by GRWP drilling teams, consisting exclusively of World Vision employees. Random assessments indicated that the quality of workmanship was of a consistently high standard. Also, the study aimed to analyse routine or commonly available field data using a replicable process, and since borehole cameras are not widely available in rural Africa, their use was precluded in the study.

One major criticism of the approach described is that it does not consider the hydrogeological conditions in which different boreholes are drilled. The reasons for this are two-fold. Firstly, this information is often simply not available and personnel engaged in drilling may have limited understanding of the geological environment in which they are operating. Secondly, the time and resource constraints under which drilling teams are operating demand practical strategies to mitigate against borehole failure, which do not require hydrogeological expertise. It is accepted that in an ideal scenario, the hydrogeological conditions for each

Photograph 1. Borehole installation

borehole would be assessed fully, but experience shows that there is often a lack of definitive information and expertise to make this feasible (World Vision, 2003). The density of boreholes in the study area was deemed sufficient to ensure that there were both operational and failed boreholes in each major geological zone, but it was not possible to determine local variations in relation to specific boreholes. It should, again, be emphasised that the study focused on practical field actions which may affect source sustainability and which can be rectified relatively easily if required.

Figure 2 presents a summary of the main variables assessed for each borehole, whether failed or operational. The respective mean values are provided for initial recorded yield (Y) in l/min; depth of borehole (D); static (or rest) water level (SWL); dynamic water level (DWL) measured during pumping test; cylinder depth (C); depth of cylinder below dynamic water level (C-DWL); and depth between dynamic water level and the bottom of the borehole (D-DWL), all in metres.

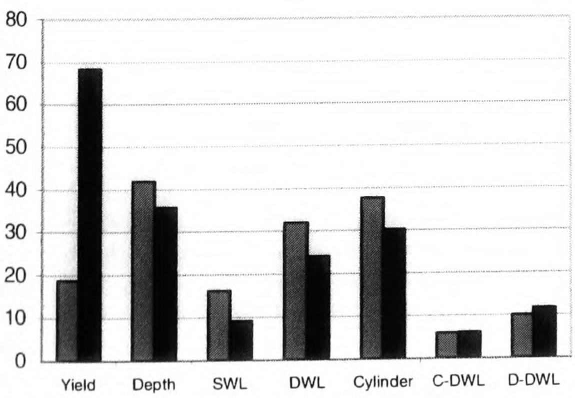


Figure 2. Summary of Data Means

As can be seen from the graph, the most apparent contrast between operational and failed boreholes was the difference between the mean values for initial yield. The mean yield for operational boreholes was 68.2 l/min, while that for failed boreholes was only 18.7 l/min. The variations in depths are less significant, but the mean values for failed boreholes are consistently greater than those for operational boreholes. Means for total depth, static and dynamic water levels are 6-8 metres greater for failed than operational boreholes. The mean value for cylinder depth below dynamic water level (C-DWL) is almost identical for both datasets at 6m, indicating consistent practice among installation teams. Similarly, the mean total depths of borehole in relation to dynamic water level (D-DWL) are very similar. These findings are examined in more detail below.

Initial yield

The initial maximum yield of each successful borehole was measured during and immediately after drilling. The mean maximum yield of 18.7 l/min for boreholes that subsequently failed was a quarter of that for operational boreholes. The respective mode was 10 l/min and the median 15.8 l/min.

The data showed that 40% of all boreholes with initial yields below 10 l/min, and which were deemed 'successful' following drilling, subsequently failed. This is significantly higher than the overall borehole failure rate of 4.5%, and indicates that this guideline figure should not be ignored.

The Government Community Water and Sanitation Agency (CWSA) has recently proposed new guidelines which stipulate that boreholes to be fitted with handpumps should have a minimum yield of 13 l/min, rather than the previously stated figure of 10 l/min (CWSA, 2003). Table 1 summarises the yields of the failed boreholes in each district in relation to the new threshold.

From the data available it can be seen that 45% of all the failed boreholes recorded had yields of less than 13 l/min but more than 10 l/min at the time of development. However, that yields should be relatively low is to be expected and caution should be taken in drawing conclusions. The total number of successful boreholes with yields between 10 and 13 l/min in the five selected districts was 85, while the total number of failed boreholes with low yields was 10. This indicates that only 12% of the total number of boreholes with yields between 10 and 13 l/min at the time of development subsequently failed. Therefore, adopting the CWSA standard for the selected areas would result in significantly fewer failures (10) but considerably more un-utilised but seemingly perfectly adequate boreholes (75). This indicates that the new figure is not likely to be a cost-effective measure in reducing borehole failure, since the number of abandoned boreholes is likely to increase significantly, meaning that 'wasted' drilling costs would far outweigh any potential benefit to a relatively small number of communities. Even where a drilled borehole has insufficient yield and a replacement borehole is rapidly drilled, there is no guarantee that this will have sufficient yield, meaning that a community might remain without an improved water supply all together.

Table 1. Initial yields of failed boreholes in the GAP

District	Total no. of failed boreholes	No. of failed boreholes with yield 10-13 l/min	Total no. of boreholes with yield 10-13 l/min
Sene	11	6	18
Atebubu	8	3	33
Sekyere East	0	0	5
Asante-Akim N	2	1	22
Kwahu N & S	1	0	7
TOTAL	22	10	85
% of failed boreholes with initial yields between 10 and 13 l/min:		45%	
% of boreholes with initial yields between 10 and 13 l/min that subsequently failed			12%

Table 2. Summary of failed boreholes in the GAP by season drilled

District	No. of failed boreholes drilled in wet season*	No. of failed boreholes drilled in dry season	Total no. of failed boreholes
Sene	10	1	11
Atebubu	6	2	8
Sekyere East	0	0	0
Asante-Akim N	2	0	2
Kwahu N & S	1	0	1
TOTAL	19	3	22
Percentage of failed boreholes drilled in the wet season			88%

* Wet season is taken as from 1st February to 31st July

Relative depths

Further variables addressed in the study were the depth of the borehole, static water level, dynamic water level and the depth to the handpump cylinder. These figures do not reveal a great deal other than the fact that, on average, failed boreholes are deeper than operational ones due to lower static and dynamic water levels, and hence average cylinder depths are also greater. The average depths of the cylinder and base of the borehole below the dynamic water level (C-DWL and D-DWL) would appear to have no bearing on whether a borehole fails in this case, since the values are almost identical for both borehole categories. What may be most significant is the relationship between borehole yield and depth, which indicates that the difference in depth does not compensate for the vast difference in yield. This suggests that boreholes with low yields should be drilled to greater depths below the DWL than those with higher yields. This was not being done in the study area.

Seasonal drilling

To provide a realistic picture of borehole sustainability, pumping tests should ideally be undertaken at the peak of the dry season, when water levels are at their deepest (MacDonald *et al.*, 2002). In practice, however, pumping tests are conducted immediately after drilling while the drilling team is still on site.

World Vision's drilling programme under GRWP was operational throughout the year and consequently boreholes were drilled in both the wet and the dry seasons. Table 2 shows the breakdown of borehole failures by season.

The table indicates that 86% of those boreholes that failed were drilled during the wet season. Based on proportional time periods and the fact that roughly equal numbers of boreholes were drilled in each season, this figure should be only 50% (corresponding to 6 months of the year). This indicates that wet season drilling is approximately six times more likely to lead to borehole failure than dry season drilling.

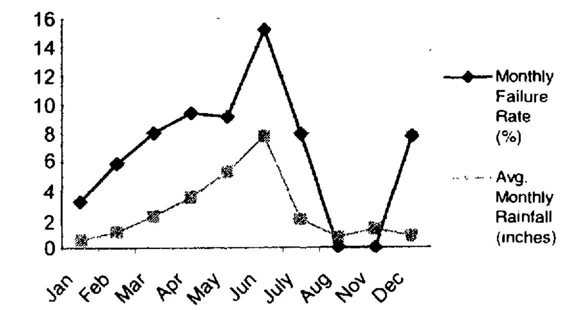


Figure 3. Monthly failure rate vs rainfall

Figure 3 shows the pattern of average monthly rainfall figures in relation to the proportion of failed boreholes as a percentage of all boreholes drilled for each month of the year. The months of September and October were excluded due to an inadequate sample size for each month, with only 2 and 6 boreholes respectively. The precipitation figures used are average monthly totals, rather than actual totals for precise months when drilling took place.

The graph demonstrates a clear relationship between the wettest months and highest failure rates, and the correlation coefficient for this relationship is strongly positive ($r = 0.865$, $df = 9$, $p<0.01$). This reinforces the finding that wet season drilling is considerably more likely to lead to borehole failure than drilling during the dry season, and suggests that drillers were not making sufficient steps to take seasonal fluctuations in water levels into account during operations. The consistent depth of cylinder installation with respect to DWL, regardless of time of year, supports this assumption. Wurzel (2001) suggests a systematic approach whereby drillers drill an additional 10 metres after sufficient yield is attained to allow for seasonal variation. It is not clear, however, how effective this measure is in countering seasonal water table fluctuations, since the approach was not adopted by the GRWP drillers.

Siting and failure rates

The relationship between borehole siting success rate and borehole failure rate by district is illustrated in Figure 4.

The purpose of this analysis was to determine whether or not rapid-onset borehole failure is more likely in hydrogeologically complex zones, i.e. those areas where borehole siting rates are low. The graph shows a weak inverse relationship between the two variables, which is reinforced by a relatively weak negative correlation ($r = -0.48$, $df = 4$, $p<0.001$). This illustrates that districts with low siting success rates are marginally more likely to have high borehole failure rates, but this relationship is not particularly strong. This can be seen from the example of Sene and Sekyere East districts, which both had borehole siting success rates of 56%, and yet Sene had 11 failed boreholes and Sekyere East had none.

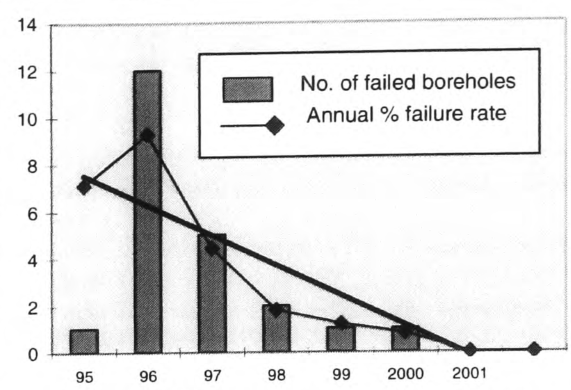


Figure 5. Failed boreholes by year of drilling

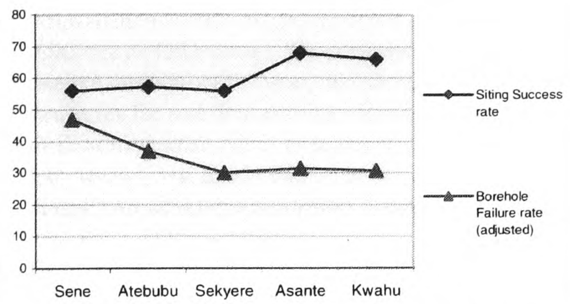


Figure 4. Siting success and borehole failure

Failure over time

It is a logical expectation that the number of failed boreholes will increase with age, and this can be seen in Figure 5. The annual failure rate reduces with decreasing age, so that no failed boreholes were drilled in 2001 and 2002, while there was a maximum number drilled in 1996 (only a very small number of boreholes were drilled in 1995). This suggests that boreholes take at least one or two years before they 'fail', and failure rates increase considerably from five years. It should be noted, however, that the survey of water points was conducted during March when the wet season had already started, so it is possible that some ephemeral boreholes contained water that had not done so during the recently ended dry season. This means that the actual total of failed boreholes may be even higher than indicated.

Discussion

Borehole sustainability, or lack of it, is rarely given significant attention in rural water supply programmes in Africa. Whilst it is not as severe a problem as inadequate handpump operation and maintenance, it does have potentially serious and negative effects on rural communities. In order to obtain detailed information as to why boreholes are failing, thorough assessments of construction and installation are required using borehole cameras. This is an expensive option and without strong institutional will it is not likely to happen in most rural African contexts. Routine field data cannot provide all the answers, but they can provide indicators to aspects of field practice which can be improved to increase sustainability.

Without longitudinal data on groundwater levels it is impossible to determine whether borehole failures are related to groundwater depletion trends. World Vision, Ghana has now recognised this problem and has recently introduced a system for quarterly monitoring of groundwater levels in boreholes. This is of crucial importance if we are to understand more about the hydrogeological environments in which we work, and to discover why systems fail. Many conventional handpump models do not facilitate easy monitoring of groundwater, and yet an inspection panel can be easily incorporated into existing designs, as used in Ghana (Photograph 2).

Photograph 2. Water level measurements

Conclusions

In order to find out more about borehole sustainability the simple solution is to obtain more hydrogeological information about the areas in which drillers are operating, and to employ more highly qualified and experienced personnel. The reality is, that this is often not possible and there are likely to always be contractors who do a reasonably competent technical job, but who do not have the level of knowledge required to gain a detailed understanding of hydrogeology. Most drillers, whether NGO or private contractors, record routine field data, such as that described, during water borehole drilling and development. This study examines whether this field data can be used to help predict borehole sustainability. The research findings suggest that there is, indeed, a limited amount of useful information that can be deduced from this data, the key points being:

- The initial measured yield of a borehole is the single largest factor that influences subsequent borehole failure. It is important that realistic guideline figures are set and adhered to. Boreholes with low yields should be drilled to greater depth with respect to DWL (and have longer screened intervals) than those with higher yields, rather than adopting a uniform approach.
- Rainfall intensity during the month of drilling has a direct influence on failure rates. It is essential that where drillers operate throughout the year, they develop compensation strategies for seasonal drilling. This is likely to involve drilling to greater depth in relation to DWL during the wet season, but groundwater levels must be recorded in order to develop appropriate strategies for different geological environments.
- Borehole failure increases with age and is most common at five years old or more, suggesting that most borehole failures are associated with reduction in yields and degradation of well construction over time.
- The siting success rate in a given area does not have a strong affect on the borehole failure rate in that area. It should not, therefore, be assumed that areas of complex hydrogeology will result in higher failure rates.

On the basis of the results obtained it is important that drillers develop field practices which take full account of seasonal groundwater variations and low borehole yields. The people involved in groundwater development must have the skills and knowledge required to be effective, so that they can acquire a real understanding of the environment in which they operate, rather than just follow rigid operational guidelines. The required yield should be matched to forecasted water demand for each specific borehole, based on the population and water usage, rather than using a fixed arbitrary guideline value. Drilling practitioners must pay special attention to low pH water and it is essential that pH values are measured both prior to construction and after development. While there are a range of techniques that can be used for borehole rehabilitation, such as acid treatment, chlorination, and hydrofracturing, the cost and management needs associated with these are often prohibitive. Prevention is better than cure, but this requires appropriate monitoring and information management.

We are now in a situation where many thousands of boreholes have been drilled in sub-Saharan Africa and little knowledge has been gained from them (MacDonald & Davies, 2002). What information we have must be used to its maximum potential, and further information should be collected and managed, in order to ensure sustainable development, on all fronts.

References

CWSA (2003) Personal communication with the author. Community Water and Sanitation Agency, Tamale, Ghana.

DFID (2001) *Addressing the Water Crisis: Healthier and more productive lives for poor people, Strategies for achieving the international development targets.* Department for International Development: UK.

Diwi Consult and Bureau d'Ingénierie pour le Développement Rural (BIDR) (1994) *Etudes d'Réhabilitation des Points d'Eau Existants.*

Driscoll, F.G., (1995) *Groundwater and Wells.* Johnson Screens, St. Paul, Minnesota, USA.

DWD (2002) *Issue Paper 1: Overview of the Water Sector, Reform, SWAP and Financial Issues.* Directorate of Water Development, Ministry of Water, Lands and Environment, The Republic of Uganda.

Foster, S., Chilton, J., Moench, M., Cardy, F. and Schiffler, M. (2000) *Groundwater in Rural Development.* World Bank Technical Paper No. 463. The World Bank, Washington.

Gyau-Boakye, P. and Dapaah-Siakwan, S. (1999) 'Groundwater: Solution to Ghana's Rural Water Supply Industry?' *The Ghana Engineer.* May 1999.

Harvey, P.A. and Reed, R.A. (2004) *Rural Water Supply in Africa: Building blocks for handpump sustainability.* WEDC, Loughborough University, UK.

Hazelton, D. (2000) The development of community water supply systems using deep and shallow well handpumps. WRC Report No, TT132/00, Water Research Centre, South Africa.

HTN (2003) *Focus on Africa, a critical need.* Network for Cost-Effective Technologies in Water Supply and Sanitation, St. Gallien, Switzerland (http://www.skat.ch/htn, accessed 12/11/03).

MacDonald, A.M. and Davies, J. (2002) *A Brief Review of Groundwater for Rural Water Supply in Sub-Saharan Africa.* British Geological Society, Nottingham, UK.

MacDonald, A.M., Davies, J. & Dochartaigh, B. (2002) *Simple Methods for Assessing Groundwater Resources in Low Permeability Areas of Africa.* British Geological Society, Nottingham, UK.

WHO (1997) *Guidelines for Drinking-Water Quality.* World Health Organisation, Geneva.

World Bank (1997) *Mali Rural Water Supply Project.* Performance Audit Report No. 16511, World Bank, Washington DC.

World Vision (2003) *Hydrogeological Report.* GRWP, World Vision, Ghana.

Wurzel, P. (2001) *Drilling Boreholes for Handpumps.* Working Papers on Water Supply and Environmental Sanitation, Volume 2, SKAT: St. Gallen, Switzerland. (http://www.skat.ch/htn/downloads/bh4handpumps.pdf)

Acknowledgements

The author would like to express his sincere thanks to World Vision, Ghana for facilitating this research and providing access to data. Particular thanks are extended to Jarvis Ayamsegna for going well beyond the call of duty.

Contact address

Peter A. Harvey - Assistant Programme Manager, WEDC, Loughborough University, Loughborough, LE11 3TU.
Email: P.A.Harvey@lboro.ac.uk

7. SUPPLY CHAINS

Proceedings of the Institution of
Civil Engineers
Engineering Sustainability 159
March 2006 Issue ES1
Pages 31–39

Paper 14067
Received 15/12/04
Accepted 24/06/05

Keywords:
developing countries/water supply

Peter A. Harvey
Research Associate, Water, Engineering and Development Centre, Loughborough University, UK

Robert A. Reed
Senior Programme Manager, Water, Engineering and Development Centre, Loughborough University, UK

Sustainable supply chains for rural water supplies in Africa

P. A. Harvey MSc, PGCE and R. A. Reed MSc, CNNA, MCIWEM

Many rural water supplies in sub-Saharan Africa demonstrate high operational failure rates, particularly those using handpumps to extract groundwater. The supply of spare parts for pump maintenance is one of the weak links in the quest for sustainability and there are very few examples of sustainable supply chains throughout the subcontinent. There are a number of key reasons for this, which are specific to the rural African context. These include: the separation of the supply of pumps from the supply of associated spares; low pump density resulting in low profits; poverty and immobility among end-users; inflexible approaches to technology choice; and restrictive policies and maintenance systems. Field research in four African countries—Ghana, Kenya, Uganda and Zambia—indicated that the supply of handpump spare parts to rural areas is not a viable stand-alone commercial activity, despite many initiatives with this ultimate aim. There is a critical need for realism in the rural water sector and for implementers to move away from the perceived wisdom that the private-sector alone is the solution to the spare parts conundrum. Integrated service provision, appropriate technology choice and, where necessary, non-profit sector options provide a multifaceted solution that must be embraced if present and future rural water services are to be sustained.

1. INTRODUCTION

Low-income communities in rural areas of developing countries generally rely on low-cost, simple technologies to abstract and deliver potable water. In the 1980s developing countries and international donors began to recognise the importance of the handpump as an appropriate technology for rural water supply.[1] Owing to the low cost and relative ease of operation and maintenance, and the availability of shallow groundwater resources beneath much of Africa and Asia, wells and boreholes with handpumps were promoted as the most viable option for rural water supply in many developing countries. Over the past two decades handpumps have consequently become the principal technology for supplying water to over 1 billion people in rural areas in at least 40 developing countries.[2] There are approximately 250 000 handpumps in Africa, but it is estimated that less than half of these are operational.[3] This is backed up by data from Uganda[4] and South Africa[5] which indicate similar operational failure rates, while an evaluation in Mali in 1997 found 90% of pumps inoperable just one year after installation.[6]

Where such water supplies fail, rural communities routinely have to rely on unprotected and unsafe sources of drinking water; this is likely to have far-reaching detrimental effects on public health and well-being. Despite these low levels of sustainability, handpumps are likely to remain a major method of delivery of rural water supplies, as they are still considered the most appropriate and popular solution in many cases.[7]

This paper presents the findings of a recent research project on the sustainability of rural water supplies in sub-Saharan Africa, based primarily on field studies in Ghana, Kenya, Uganda and Zambia. This project evaluated existing water systems and the institutional and financial arrangements in place for their operation, management and maintenance. From the research it is clear that there are many reasons for low sustainability, but one of the predominant causes is the provision of spare parts for repair and maintenance.[8] Satisfactory distribution of spare parts has been achieved in only a few areas in Africa.[9] This problem has been widely recognised for several years now, and has led to a number of developments to promote sustainable supply chains for rural water supplies; an example is the 'supply chains initiative' led by the Water and Sanitation Program (WSP) of the World Bank. Such initiatives have had limited impact to date and focus largely on the private-sector provision of spare parts for community-based maintenance.[10] To date there is little evidence to suggest that the private-sector approach is delivering sustainable supply chains. There consequently remains the need to examine and question prevailing opinion and practices in the rural water supply sector and seek innovative solutions to the supply chain challenge.

2. CHALLENGES FOR SPARE PARTS SUPPLY CHAINS

The majority of rural water supplies in sub-Saharan Africa are community owned and community managed.[11] This means that the user community owns the water supply and has overall responsibility for its operation and maintenance. This is often known as village-level operation and maintenance (VLOM).[12] In general, this is fulfilled through the formation of a community water committee that is responsible for setting and collecting water tariffs, operating the system and managing maintenance and repair activities. Committee members are usually responsible for purchasing spare parts and undertaking repairs, although in some cases this may be contracted out to private operators. An xample of the latter approach is the area pump mechanic model, hereby a private individual provides a maintenance and epair service to several communities in a given area.[13] Members of the general public are normally expected to ontribute to initial system installation costs and to meet all ngoing maintenance and repair costs, including the cost of pare parts, through the regular payment of appropriate water ariffs.

The overall goal of an effective and sustainable supply chain or spare parts is to ensure that the four 'A's are met—that is, hat spare parts are

(a) available: the required components are in stock or can be rapidly delivered
(b) accessible: customers are aware of where to find outlets for spares and the nearest of these is within easy travelling distance
(c) affordable: priced within the means of the target customers
(d) appropriate: of correct specification and good quality.

In order to ensure that these requirements are fulfilled, there must be a sustainable chain of incentives from the manufacturer to the eventual customer. The majority of handpumps found in sub-Saharan Africa outside South Africa are manufactured in India, meaning that, in general, pumps and components must be imported. This is primarily because most customers opt for the cheapest price internationally and local manufacturers are unable to produce products as cheaply as their foreign counterparts. Similarly, other rural water technologies such as solar-powered pumps, shaft-driven borehole pumps and wind-powered pumps also rely on imported components. Meanwhile, most customers requiring spare parts are community water committees or private mechanics based in rural areas. This means that there must be a supply and distribution network for the recurrent delivery of spares from the point of manufacture to the points of use, at an acceptable price and quality. Ideally, water committees should be able to obtain spares the same day as a fault arises in order to facilitate rapid and effective repair of their water system.

Water delivery technologies are most commonly procured by external support agencies, non-governmental organisations (NGOs) or governments under development programmes, and systems are constructed and installed by agency staff or trained local skilled workers. The predominant approach to the supply of spares in the past was for implementing agencies, namely government or NGOs, to maintain stocks of spare parts and provide these to users at nominal cost or free of charge. In recent years, however, responsibility for the provision and distribution of spare parts has been given to the private-sector ostensibly in order to increase sustainability levels.[14] The rationale for this change in approach is that previously many NGOs would undertake projects in specific areas for several years and then move away without leaving a sustainable supply chain in place. This meant that once the NGO had left an area, components would not be available locally and systems would soon fall into disrepair. The private-sector model relies on a 'business approach' whereby private-sector members have sufficient incentive to become involved and to maintain their involvement. The primary incentive for the private-sector is profit, whether generated directly or indirectly.

2.1. Barriers to sustainability

While handpumps remain the predominant technology choice for improved rural water supplies in Africa, there are very few examples, if any, of sustainable private-sector supply chains for handpump spare parts.[15] There are a number of fundamental reasons for this, namely

(a) limited profit for private-sector involvement
(b) independent pump procurement procedures
(c) poverty and immobility among end-users
(d) government and donor policies that favour importers
(e) dependence on community-based maintenance systems
(f) inflexible approaches to technology choice.

2.1.1. Profit. The biggest barrier to sustainability is the lack of profit for the private-sector. Selling spare parts is not generally a profitable business and therefore the willingness of the private-sector to take on this commercially uninteresting activity is minimal.[14] Many donors have promoted private-sector participation in spares supply by providing a 'seed fund' to private enterprises to stimulate commercial involvement and viability.[16] The principle behind this approach is to provide a private company (often an existing hardware store) with a stock of spare parts (at nominal cost or free of charge), to set fixed retail prices for parts, and to instigate an advertising and marketing campaign. The company is then expected to use the profits generated from sales to replenish stocks from a central supplier and hence sustain the supply of spare parts. Such initiatives have been implemented in many African countries, including Ghana, Malawi and Zambia, but this approach has not proved successful to date owing to low turnover and low profits, meaning the retailer has little ongoing incentive to invest profits in new spares. This is particularly the case for small businesses in which cash flow is critical to survival. In many cases sustainability relies on the goodwill of the retailer rather than sound commercial sense, as illustrated by a recent study in Mozambique and Malawi which indicated that private suppliers did not make sufficient profit from the provision of spares to motivate them and only sold spares as a community service.[17]

The reasons for low profitability are simple. The density of handpumps in most rural areas of Africa is low, and since most pumps are reasonably reliable (typically breaking down only once every two years or more), the demand for spare parts is also low. Individual profit margins for most 'consumable' components are very small (for example, the rubber seal O-ring for an Afridev pump generally needs replacing most often but might generate a profit of less than US$1 for the retailer[18]) and prices cannot simply be raised as customers are unwilling or unable to pay more. Consequently, capital turnover is very low and yet retailers must keep many components in stock. This ties up capital which could be used to invest in more profitable products. High inflation rates in many developing countries further compound the problem. Since most components are imported, prices are linked to foreign currency and hence devaluation of the local currency means that retail prices must be continuously adjusted to maintain profits and ensure that stock can be replenished.

2.1.2. Procurement. The procurement of spare parts is often separated from the procurement of pumps and major system components. Most implementing agencies buy pumps in bulk, especially where the rural water supply 'project' approach of installing several hundred pumps in a given area is used. This means that manufacturers and suppliers are selected primarily on the basis of cost and consequently many agencies order pumps directly from manufacturers overseas. The external private-sector is keen to compete for such contracts since the profit margins on pumps are attractive. They have no incentive, however, to supply spare parts since these provide negligible profits and, so long as they continue to receive large orders for pumps, business remains viable. This practice means that an isolated supply chain must be set up for the ongoing supply of spare parts, for which there are few incentives for the private-sector, whether indigenous or external.

Figure 1 illustrates the contrast between the typical route for the provision of spares and that for the provision of pumps. The diagram represents the typical scenario in which handpumps are manufactured outside the country of use, as indicated by the dotted black line. The step from the suppliers of key components and raw materials (C) to the manufacturer is the same for pumps and spares, but after that the routes diverge completely. The handpump is usually purchased directly from the manufacturer by the donor or government, although a few donors may purchase from an in-country agent. It is then delivered to the project and finally installed by the private-sector. In contrast, the spare parts are purchased from the manufacturer by an agent, these then pass down the supply chain to spares outlets (SP) distributed around the country, from where they are purchased by area mechanics and finally by the users.

The large number of necessary 'profit steps' that exist between the user and the manufacturer are indicated in the diagram. This inevitably leads to higher prices for the user while minimising profits for each step in the supply chain. Reducing the number of steps can help to increase the efficiency and effectiveness of the supply chain. Promoting local production and local agents selling directly to users, and linking parts with pumps can help to reduce the number of steps.

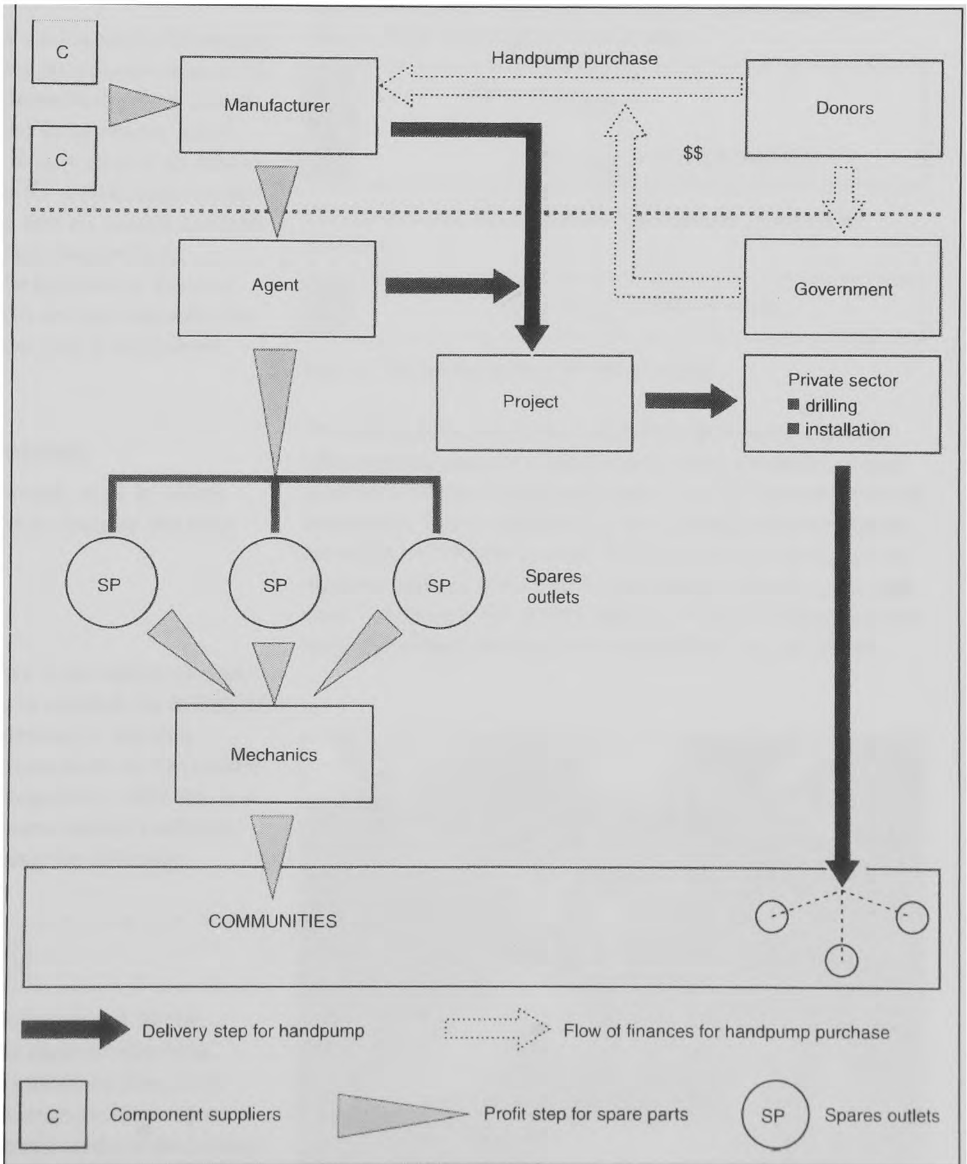


Fig. 1. Typical private sector spare parts supply chain

2.1.3. Poverty and immobility. Poverty among end-users poses specific problems to supply chain management in a rural African context. Most users of rural water supplies are relatively poor, which means that they are relatively immobile and do not have easy access to transportation to travel long distances to purchase spare parts. Spares outlets must therefore be relatively close to rural communities. Another effect of poverty is limited economic development, which means that the level of commercial and industrial activity in most rural areas is also limited. This makes it difficult to add handpump spares to the existing product lists of retailers. Where retailers have large turnovers they may be able to afford to lock up capital in spare parts even though they make very little profit from this new product line, but this is rarely possible in a rural context.

2.1.4. Policy. Government policies and strategies may also act as indirect barriers to sustainable supply chains. Relaxation of import duties on water technologies (as an aid to rural development) may favour agencies importing pumps, but does ittle to encourage local manufacture and procurement, which would be likely to help stimulate local supply of spares. Governments can also provide incentives for the development of local private enterprise and ensure fair practice through appropriate regulation and legislation.

2.1.5. Maintenance systems. Reliance on the community management model of maintenance also creates additional demands on the supply chain, which make it unsustainable. Since community management decentralises control to scattered communities this means that spare parts must be available locally to rural populations, which is often not commercially viable. Alternative centralised maintenance systems that cover many communities mean that spares do not need to be available at as many levels, and put less stress on the supply chain. Those responsible for such systems tend to be based in larger settlements and have their own means of transportation, and hence can access spares at national or regional level more easily. The continued predominance of community management creates the need for a lowest level in the chain that is unviable, and simply makes the sustainable supply chain goal harder to achieve.

2.1.6. Technology choice. Reliance on imported technologies using specialised components is perhaps the primary cause of the supply chain challenge. Where the selected technology can be manufactured, maintained and repaired using resources and equipment that are already available locally there is no need to set up a new supply chain specifically for a rural water supply technology. If pumps use components that are already available in plumbing stores or car spares retailers, the need for sector-specific strategies disappears. Unfortunately, however, the majority of rural water technologies are still imported and will only operate effectively in the long term if specialised spare parts are available.

3. THE PROFIT INCENTIVE EXPOSED

Since the private-sector 'business approach' must be driven fundamentally by profit it is important to examine this issue in more detail.

3.1. System density

In order to test the commercial viability of the supply of spare parts at the user level, one approach is to establish the density of systems required to produce enough demand to generate sufficient turnover of spares and sufficient profit for the retailer. The minimum density (systems/km^2) required to fulfil this in a particular context is defined as the system density breakpoint (SDB), which can be determined by using the following equation

$$\mathrm{SDB} = \frac{P_{\min} t}{\pi p_a R_a^2}$$

where $P_{\min}$ is the minimum annual profit required by the retailer for commercial viability (this is likely to vary from retailer to retailer but an average value based on interviews with retailers can be used); p_a is the average profit per spare part weighted for frequency of replacement need; t is the average time period (in years) between each spare part required for any given pump (this will depend on selected technology, quality of components, groundwater conditions, etc.) and; R_a is the radius of access (in km) which is defined as the average of the maximum distances from the retailer to potential customers (this determines the area realistically served and is heavily influenced by transportation links, topography, geographical and political boundaries).

The following subsection presents a worked example to calculate the SDB (in pumps/km^2) for the India mark II handpump in Ghana (Fig. 2): this is one of the most widespread handpumps in Africa. Since the average profit, p_a and the average time between breakdowns, t (which generally decreases with the age of the pump) are difficult to assess, this is intended purely as an approximation to test commercial viability.

3.1.1. Calculating system density breakpoint. For an India mark II pump, $t = 2$ years, and the study area in Ghana radius of access = 20 km. Based on interviews with retailers, the average profit per part weighted for frequency of use is only US\$1 and an annual profit of at least US\$100 is required to make the supply of spares commercially worthwhile. This is a conservative figure, based on minimum figures quoted and $P_{\min}$ is likely to be higher in most cases

$$\begin{aligned}\mathrm{SDB} &= P_{\min} \frac{t}{\pi p_a R_a^2}\\ &= 100 \times \frac{2}{\pi 20^2} = 0{\cdot}159\,\text{pumps/km}^2\end{aligned}$$

The number of pumps required in given area of access is, therefore

$$N_{\min} = P_{\min} \frac{t}{p_a} = 100 \times \frac{2}{1} = 200$$

that is, 200 pumps within 20 km of outlet.

This example illustrates the relatively high density required, still assuming that the retailer expects only a nominal annual profit of \$100 and that all pump users visit the same outlet to buy spare parts. This is supported by the findings of the handpump manufacturer Vergnet in west Africa,which has established an optimum ratio of 200–300 Vergnet handpumps per spare parts shop.[19] Although 200 pumps within a radius of 20 km does not seem like a huge number, 0·159 pumps/km^2 is a far higher

Fig. 2. India mark II handpump in Ghana

density than is usually found in sub-Saharan Africa. The density of rural populations in Africa is generally quite low, and consequently so is the density of handpumps. A study of eight districts in central Ghana indicated a maximum density of 0·070 pumps/km^2 (only 40% of the required density) and an average of only 0·052 pumps/km^2, even in more populous areas where there had been intensive handpump installation programmes for more than a decade.[20]

3.2. The need for realism

The above example illustrates that the profit incentive alone is not sufficient to make the supply of spare parts an unsubsidised stand-alone commercial activity in the rural African context. Experience would suggest that virtually nowhere in sub-Saharan Africa are pump densities sufficient to generate adequate demand for spares and sufficient turnover and profit for the private-sector. It is essential that implementing agencies accept that the unsubsidised private-sector approach to the provision of spares is unviable. Although this fact is becoming more widely acknowledged, it is unfortunate that many organisations continue to promote, and attempt to initiate, stand-alone private-sector supply chains for spare parts.[21]

4. SUSTAINABLE SOLUTIONS

It is the firm conviction of the present authors, based on recent research, that unsubsidised private-sector supply chains for spare parts will only stand a chance of being sustainable if *at least one* of the following three criteria is met.

(*a*) Private sector companies supply pumps and related services, as well as spare parts, at all levels.
(*b*) Community ownership and management of water supplies is replaced with more centralised public–private management systems or privately owned water supplies.
(*c*) Technologies are installed that use only components which are already readily available locally for other purposes.

If none of these criteria are fulfilled then alternative strategies for spares supply, such as subsidisation and non-profit approaches, must be adopted.

4.1. Procurement and service linkages

Successful supply chain management requires a change from managing individual functions to integrating activities into key supply chain processes.[22] Strengthening links between pumps, services (such as borehole drilling and pump installation) and parts can therefore increase the viability of supply chains. Procurement practices of donors can have a major influence on this and can stipulate roles and responsibilities of manufacturers within contracts. This requires a shift from selecting pump suppliers by lowest price internationally, to selecting local suppliers who can also provide spares and related services. This may result in slightly higher cost to the donor in the short term, but is a more sustainable long-term option. Government decentralisation policies can also contribute by encouraging the procurement of pumps and services at district or local level. Where successful, this approach can stimulate supply chains down to district level, which may or may not provide sufficient coverage. Its sustainability remains dependent on adequate ongoing demand for pumps.

According to Sohail and Baldwin[23] procurement through partnerships between communities and formal/informal small-scale enterprises offers new opportunities for the successful introduction of sustainable infrastructure. Fig. 3 presents an alternative model for spare parts supply whereby spares outlets are replaced with pumps, spares and technical service suppliers (PSTs). By enabling communities themselves to purchase pumps at the lowest level possible—that is, as close to the community as possible—rather than agencies procuring pumps for them, this ensures that spare parts are also available at this level. Where possible, the private enterprise can also provide technical services, such as drilling and pump installation and repair, to diversify profit-making activities. A recent study in Uganda indicated a strong desire among local spare parts dealers to diversify activities in this way to increase profits.[24] The advantage of such a programmatic approach is that pumps are purchased routinely from the local suppliers on a continual basis, rather than by occasional bulk order, meaning that they generate continuous revenue. The cost of this to the implementing agency may be slightly higher, but this should be a price worth paying to promote sustainability. Promoting local (in-country) manufacture (Fig. 4), using local resources where possible, also reduces the number of profit steps and can help to ensure appropriate quality control mechanisms are put in place, as well as to increase local economic activity.

The linking of pumps, technical services and spare parts can go a long way to increasing the effectiveness of a supply chain, but there remains the barrier of the lowest appropriate level. Making pumps available at regional or district level may be achievable, but to go beyond this is likely to be problematic. Where community management is the norm, this may mean that customers still have to travel considerable distances to access spares. The level of commercial activity within a country can have a big impact on the level of coverage that such an approach can achieve. Where commercial activity is relatively high, it may be possible to add handpump spares to the existing product lists of retailers who can afford to sustain involvement even where they make negligible profit from such a venture.

Linking products and services can increase the viability of supply chains and provide considerably improved access for rural communities, but this requires considerable change in the priorities and practices of donors and implementers. What is undeniable is that there is no universal, proven solution.

4.2. Public–private maintenance systems

It can be argued that the community management option for rural water supplies creates unreasonable demand on the supply chains for spares. The needs of the supply chain are considerably reduced where VLOM is replaced by public–private operation and maintenance (PPOM), whereby the private-sector is responsible for operation and maintenance regulated by local government. Instead of needing spares outlets in most rural towns where community members can access them, these will only be needed in the larger regional settlements where private companies can access them. Two examples of PPOM models are the total warranty scheme, whereby a pump manufacturer supports local enterprises to

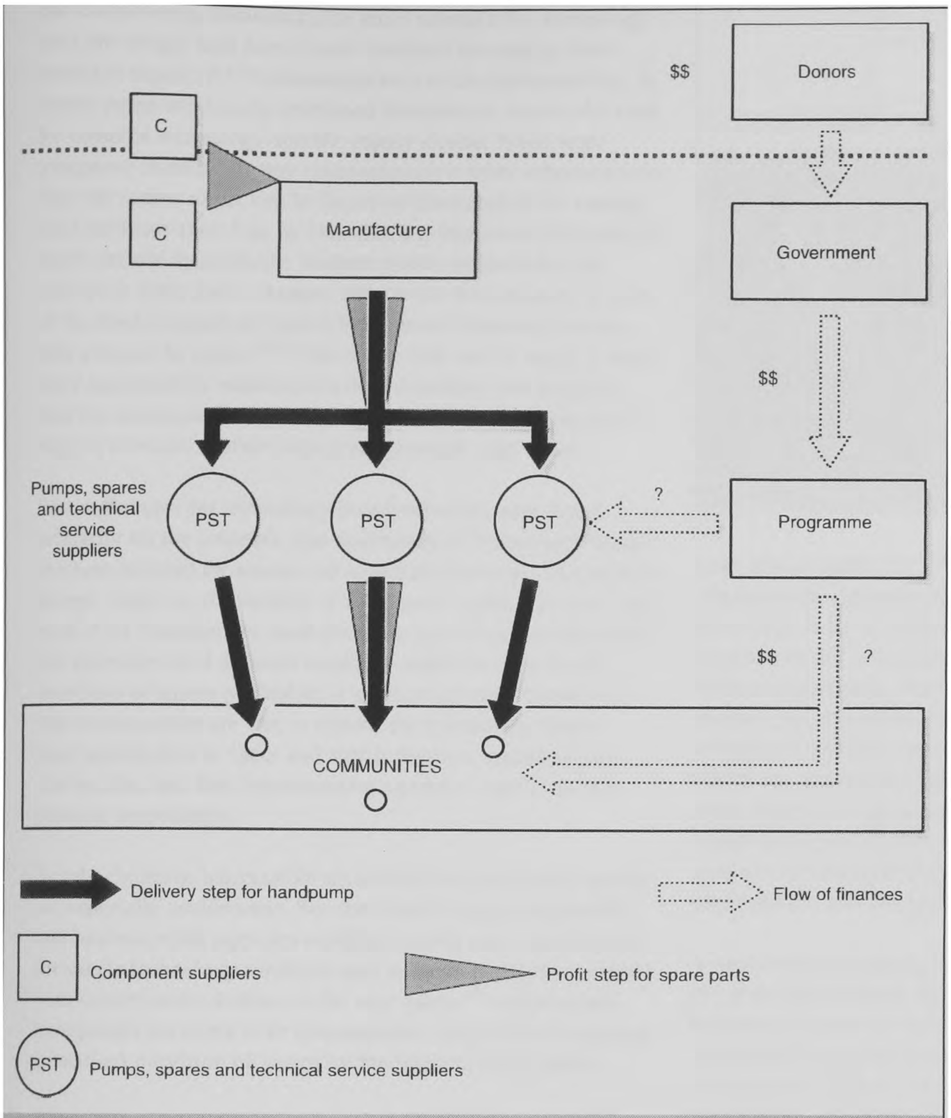


Fig. 3. Linked private-sector supply chain for pumps and spares

This can create conflicts of interest and mistrust, which may make sustainable management difficult. Where the system or pump is owned by a private individual, and members of nearby communities are charged by the pump owner to draw water, the owner has a clear personal incentive to obtain the spare parts required to maintain the pump in a good state of repair. As long as the pump is operable the owner receives a regular income.

The leasing concept is an expansion of this principle, whereby a private company owns and operates a large number of pumps and users pay the company a monthly tariff.[26] The onus is again on the owner (the company) to procure spare parts and ensure that systems are operating, otherwise users are likely to suspend payments and the company may go out of business. Despite the success of such ventures, to date there are only isolated examples of privately owned water systems providing water to rural communities in Africa. There remains a strong need to test the wider application of private-ownership models.

provide spares and technical services for which users pay an annual contract fee; and the water assurance scheme, whereby the user community owns the water supply and pays a private company to undertake routine maintenance, repairs and upgrades. In each case the government has a key role to play in the regulation of the private-sector supplier and monitoring of water supplies. The application of such models has been limited to date, but pilot studies indicate that they provide significant potential for increased sustainability.[25]

PPOM models place the responsibility for the procurement of spares with private service providers who have greater mobility than most members of rural communities. The application of this approach may be limited by the density of communities served, the willingness of community members to pay for services and the capacity of the private-sector, but there is a strong need for more pilot studies to assess the viability of different models in various rural environments.

4.3. Private ownership

The typical rural water system is owned by a 'community' consisting of people with differing needs and priorities.

4.4. Appropriate technology

The simplest solution to the spare parts conundrum is only to use simple technologies that do not require specialist spare parts

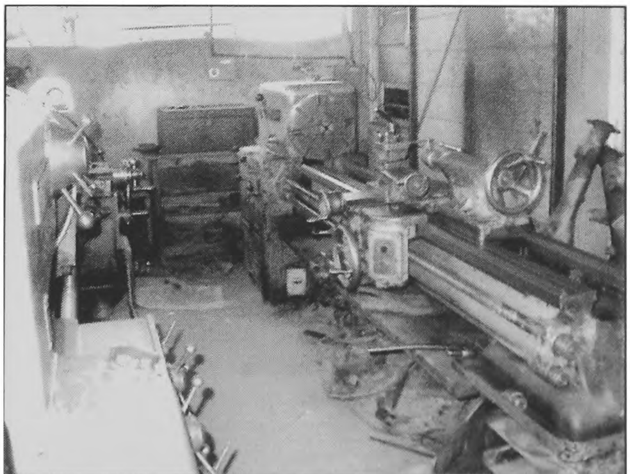


Fig. 4. Local workshop for manufacture of handpumps in rural Kenya

and components. Invariably, the more complex the technology used, the longer (and hence more complex) the supply chain needed to support it.[27] Technologies such as the rope pump (Fig. 5), bucket pump and locally developed handpumps, remove the need for complex technology-specific supply chains. While some pumps use standard factory components it is more important that they use spares which can be found or fabricated in the average rural hardware store (Fig. 6). Likewise, it is important that tools for repair are widely available. Various studies indicate that the rural poor often prefer cheaper, shorter-life technologies, in spite of the need to repair or replace them more frequently, because they are easy to repair.[28,29] This shows that ease of repair is often more important to communities than durability and suggests that the argument for high-quality technology and components may be externally driven rather than demand responsive.

Past arguments for technology standardisation were based primarily on the principle that uniformity of technology would increase demand for spares and associated services. As has been shown, however, the density of rural water systems is such that even if all communities used the same type of pump this would not guarantee that demand would be sufficient to make the provision of spares profitable. It is therefore more important that communities are free to choose the technology that is most appropriate to them and which they are confident they can sustain, and that implementing agencies respond to this demand accordingly.

Supply chains in inaccessible areas with low population density are especially problematic. For this reason many communities and implementing agencies working in such environments opt for simple technology solutions such as hand-dug wells equipped with bucket-and-windlass or the rope pump.[30] Conventional handpumps are likely to be inappropriate unless there is ongoing subsidised provision of spares by the implementing agency.

If the predominant procurement practices, maintenance systems and technologies remain as they are, alternatives to the traditional private-sector 'business approach' must be developed.

4.5. Non-profit options

A non-traditional approach to private-sector participation in supply chains is to seek subsidies from the private-sector, in the form of sponsorship. Baumann[31] suggests that sponsorship of

Fig. 5. Simplified technology—the rope pump

Fig. 6. Private-sector supplier of pumps and spare parts

spare parts supplies for rural water could be attractive to big companies for advertising purposes. There are several ways in which this could be implemented. One approach is for the company to pay advertising fees directly to the spares retailers to display sponsorship slogans and logos on signposts used to promote spares outlets. Alternatively, a large company with widespread visibility could add spare parts to the products it distributes and advertise the fact that it is supporting the rural water supply. The sponsorship approach has not been tried on a large scale to date, but can make effective use of the social incentive of helping ensure clean water is available to poor rural communities, and the good opinion gained from this.

A sponsorship approach to rural water supply has been attempted in South Africa where the cost of maintenance and repair (including spares) for the play pump is met by the advertising fee paid by the sponsor to display their advertisement on the elevated tank. This is a new approach which appears to work best beside roads where the advertisements will be seen by many.[32]

The use of non-profit-making organisations (such as churches, indigenous NGOs or local government departments) in spares provision has been suggested as a more viable alternative to the private-sector approach for many situations.[33] Recent research in Malawi has indicated that indigenous religious organisations provide a viable long-term option, so long as they have a reliable funding base, and examples are given of supply chains that have been in operation for 10–20 years.[34] Although the number of such organisations with adequate capacity, stability and motivation may limit coverage, they have proven to be an effective alternative where the private-sector approach is unsuccessful. They should not, therefore, be automatically dismissed as unsustainable.

5. CONCLUSIONS

(*a*) There is no single solution that will ensure that supply chains for rural water supplies in sub-Saharan Africa are sustainable. The population and service density, level of industrialisation and wealth of customers will all influence the best choice for each particular situation.

(*b*) It is clear that the private-sector business approach to the supply of spare parts is not viable unless integrated with the provision of pumps and/or technical services. This requires a paradigm shift away from externally driven donor-led projects to local rural services that develop local capacities and promote local economic growth.

(c) A parallel shift from community management to public–private management and maintenance also provides significant opportunities for sustainable economic growth and sustainable water provision.

(d) Technology choice has a key role to play, and simple, local options may considerably reduce the problems created by imported technologies.

(e) In some situations, particularly where populations are sparsely distributed and access is difficult, it must be accepted that non-profit or subsidised approaches are likely to be the only viable supply chain option.

(f) There is an acute need for realism among donors, governments, policy-makers and implementers if supply chains are to be sustainable and if the benefits of potable water in poor rural communities are to be realised on a long-term basis throughout sub-Saharan Africa.

6. ACKNOWLEDGEMENTS

Much of the data for this paper were gathered as part of a Knowledge and Research (KaR) project 'Guidelines for Sustainable Handpump Projects in Africa' (R7817), funded by the Department for International Development (DFID) of the British Government, and conducted by the Water, Engineering and Development Centre (WEDC), Loughborough University. Opinions noted within this paper do not necessarily represent those of DFID but are solely those of the authors.

REFERENCES

1. Carter R. C., Tyrrel, S. F. and Howsam P. Lessons learned from the UN water decade. *Journal of the Institution of Water and Environmental Management*, 1993, 7, No. 6, 646–650.
2. Rural Water Supply Network (RWSN). *The Handpump.* Network for Cost-Effective Technologies in Water Supply and Sanitation, SKAT, St. Gallen, Switzerland, 2004.
3. Rural Water Supply Network (RWSN). *Focus on Africa.* Network for Cost-Effective Technologies in Water Supply and Sanitation, SKAT, St. Gallen, Switzerland, 2004.
4. Directorate of Water Development. *Issue Paper 1: Overview of the Water Sector, Reform, SWAP and Financial Issues.* DWM, Ministry of Water, Lands and Environment, The Republic of Uganda, 2002.
5. Hazelton D. *The Development of Community Water Supply Systems Using Deep and Shallow Well Handpumps.* Water Research Centre, South Africa, 2000,WRC Report No, TT132/00.
6. World Bank. *Mali Rural Water Supply Project.* World Bank, Washington DC, 1997, Performance Audit Report No. 16511.
7. Harvey P. A. and Reed R. A. *Rural Water Supply in Africa; Building Blocks for Handpump Sustainability.* Water, Engineering and Development Centre (WEDC), Loughborough University, UK, 2004.
8. Parry-Jones S., Reed R. and Skinner B. H. *Sustainable Handpump Projects in Africa: A Literature Review.* Water, Engineering and Development Centre (WEDC), Loughborough University, UK, 2001.
9. Baumann E. *Water Lifting. Series of Manuals on Drinking Water Supply*, Vol. 7. SKAT, St. Gallen, Switzerland, 2000.
10. Oyo A. Developing RWSS supply chains. Creating an enabling environment for small and medium enterprises to deliver goods and services in the rural water supply and sanitation sector. *Proceedings of the 27th WEDC Conference, Lusaka, Zambia*, 2001.
11. Schouten T and Moriarty P. *Community Water, Community Management–From System to Service in Rural Areas.* ITDG Publishing/IRC, 2003.
12. Arlosoroff S., Tschannerl G., Grey D., Journey W., Karp A., Langenegger O. and Roche R. *Community Water Supply: The Handpump Option.* The World Bank, Washington DC, 1987.
13. Colin J. *Lessons Learned from Village Level Operation and Maintenance.* WELL, Water, Engineering and Development Centre (WEDC), Loughborough University, UK, 1999, WELL study Task 162.
14. Oyo A. *Creating Successful Private Sector Supply Chains: A Resource Guide for Rural Water Supply and Sanitation Practitioners.* Water and Sanitation Program (WSP), Washington DC, 2002.
15. Baumann E. *Water Lifting.* Series of Manuals on Drinking Water Supply, Vol. 7. SKAT, St. Gallen, Switzerland, 2000.
16. Reed R. A., Skinner B. H. and Harvey P. A. *Guidelines for Sustainable Handpump Projects in Africa: Inception Report.* Water, Engineering and Development Centre (WEDC), Loughborough University, UK, 2002.
17. Batchelor S., McKemey K. and Scott N. *Exit Strategies for Resettlement of Drought Prone Populations (Project Technical Report).* Gamos, Reading, UK, 2000.
18. Harvey P. A., Ikumi P. N. and Mutethia D. K. *Sustainable Handpump Projects in Africa: Report on Fieldwork in Kenya.* Water, Engineering and Development Centre (WEDC), Loughborough University, UK, 2003.
19. Oyo A. *Creating Successful Private Sector Supply Chains: A Resource Guide for Rural Water Supply and Sanitation Practitioners.* Water and Sanitation Program (WSP), Washington DC, 2002.
20. World Vision. *Ghana Rural Water Project Phase III Evaluation.* World Vision Ghana, 2003.
21. SKAT. *Skat News–Newsletter of the Skat Foundation and Skat Consulting*, 2004, No. 02, September. SKAT, St. Gallen, Switzerland, 2004.
22. Lambert D. M. Supply chain management: what does it involve? *Supply Chain and Logistics Journal*, 4, No. 4, 2001, 1–25.
23. Sohail M. and Baldwin A. Urban infrastructure procurement in low income countries. *Proceedings of the Institution of Civil Engineers, Engineering Sustainability*, 2003, 56, No. 2, 87–93.
24. Baumann E., Okuni P. and Wandera S. *Supply Chains for Rural Water Supply in Uganda.* HTN, SKAT Foundation, St. Gallen, Switzerland, 2002.
25. Bernage F. Local private-sector involvement: the Mauritania experience. *Proceedings of a SKAT HTN Workshop on Civil Society and Government Partnerships in RWS*, Hyderabad, India, March 2000. SKAT, St. Gallen, Switzerland, 2000.
26. Van Beers P. Leasing, a new handpump O&M concept. *Proceedings of the 27th WEDC Conference, Lusaka, Zambia*, August 2001. Water, Engineering and Development Centre (WEDC), Loughborough University, UK, 2001.

27. WATER AND SANITATION PROGRAM. *Supply Chains: A Global Initiative*. WSP, Washington DC, 2000.
28. BROCKLEHURST C. *Promoting Robust Supply Chains for Rural Water and Sanitation Goods and Services*. Phase 1 Synthesis Paper, WSP, Washington DC, 2001.
29. BRESLIN E. D. The demand-responsive approach in Mozambique: why choice of technology matters. *Waterfront*, No. 16, 2003.
30. WATER AND SANITATION PROGRAM. The rope pump: private sector technology transfer from Nicaragua to Ghana. *Water and Sanitation Programme, Supply Chain Links to Sustainability* No. 5, February 2001.
31. BAUMANN E. *Water Lifting*. Series of Manuals on Drinking Water Supply, Vol. 7. SKAT, St. Gallen, Switzerland, 2000.
32. HARVEY P. A. and KAYAGA S. M. *Guidelines for Sustainable Handpump Projects in Africa: South Africa Report*. Water, Engineering and Development Centre (WEDC), Loughborough University, UK, 2003.
33. DEGABRIELE J. *Improving Community Based Management of Boreholes; A Case Study from Malawi*. BASIS, University of Wisconsin-Madison, USA, 2002.
34. ALEXANDER Z. J. *Non-profit Sector Supply of Handpump Spares - Lessons from Malawi*. Water, Engineering and Development Centre (WEDC), Loughborough University, UK, 2003.

References

Annan, K.A. (2000) *'We the Peoples' The role of the United Nations in the 21st Century.* United Nations, New York.

Arlosoroff, S., Tschannerl, G., Grey, D., Journey, W., Karp, A., Langenegger, O. and Roche, R. (1987) *Community water supply: the handpump option.* The World Bank, Washington DC.

Baumann, E. (2005) *Common RWSN Context.* Discussion Paper, St. Gallen, SKAT /RWSN.

Cambridge Dictionary (2007) *Cambridge Advanced Learner's Dictionary Online.* Cambridge University Press, UK. (http://dictionary.cambridge.org)

Carter, R.C., Tyrrel, S.F. and Howsman, P. (1999) "Impact and Sustainability of Community Water Supply and Sanitation Programmes in Developing Countries." *Journal of the Chartered Institution of Water and Environmental Management,* 1999, 13 (3) 292-296.

Davis and Brikké (1995) *Making Your Water Supply Work: Operation and maintenance of small water supplies.* IRC, Delft, The Netherlands.

DFID (2001) *Addressing the Water Crisis: Healthier and more productive lives for poor people, Strategies for achieving the international development targets.* Department for International Development, UK.

DWD (2002) *Issue Paper 1: Overview of the Water Sector, Reform, SWAP and Financial Issues.* Paper for the Joint GOU/Donor Review for the Water and Sanitation Sector 24-26th September 2002, International Conference Centre, Kampala. Directorate of Water Development, Ministry of Water, Lands and Environment, The Republic of Uganda.

Hazelton, D. (2000) *The development of community water supply systems using deep and shallow well handpumps*. WRC Report No, TT132/00, Water Research Centre, South Africa.

Luckhurst, J. (2003) "Sustainability Indicators for the Water Industry". *Proceedings of the Institution of Civil Engineers: Engineering Sustainability,* 56 (3), 135-137.

Macdonald, A.M. and Davies, J. (2000) *A Brief Review of Groundwater for Rural Water Supply in Sub-Saharan Africa.* Technical Report WC/00/33, Overseas Geology Series, British Geological Survey, UK.

MLGH (2007) *National Rural Water Supply and Sanitation Programme (2006-2015),* Ministry of Local Government and Housing, Government of the Republic of Zambia.

Moss, S. (2003) "Re-evaluating Emergency Water Supply Interventions in 'Complex Droughts' in Southern Africa." *Proceedings of 29th WEDC Conference,* Loughborough University, 2003, pp. 336-339.

Olowu, D. (1994) *Decentralisation, Democratisation and Development in Africa,* paper presented at the conference on Democratic Decentralisation in Asia and Africa, Institute of Commonwealth Studies, University of London, 21 September 1994.

Oyo, A. (2002) *Creating Successful Private Sector Supply Chains: A resource guide for rural water supply and sanitation practitioners.* WSP, Washington D.C.

Parry-Jones, S., Reed, R. and Skinner, B.H. (2001) *Sustainable Handpump Projects in Africa: A literature review.* WEDC, Loughborough University, UK.

RWSN (2004) *The Handpump.* Network for Cost-Effective Technologies in Water Supply and Sanitation, SKAT, St. Gallen, Switzerland.

Schouten, T. and Moriarty, P. (2003) *Community Water, Community Management – From system to service in rural areas.* ITDG Publishing / IRC.

WELL (1998) *DFID Guidance manual on water supply and sanitation programmes.* WELL, WEDC, Loughborough University, UK.

WHO/UNICEF (2000) *Global water supply and sanitation assessment 2000 report.* WHO/UNICEF, New York.

World Water Council (2002) *UN Consecrates Water as Public Good, Human Right.* www.worldwatercouncil.org/download/UN_water_public_good.pdf.

Appendix 1: List of publications submitted

Harvey, P.A. "Poverty Reduction Strategies: Opportunities and threats for rural water supplies in sub-Saharan Africa". *Progress in Development Studies,* 8(1), 2008, pp. 115-128.

Harvey, P.A., Uno, J. and Reed, R.A., "Management of Rural Water Services in Sub-Saharan Africa". *Proceedings of the Institute of Civil Engineers: Civil Engineering,* 159(4), November 2006, pp. 178-184.

Harvey, P.A. "Cost-Determination and Sustainable Financing for Rural Water Services in Sub-Saharan Africa". *Water Policy Journal,* 9 (4) 2007, pp. 373-391.

Harvey, P.A. and Reed, R.A. "Community-Managed Water Supplies in Africa: Sustainable or Dispensable?". *Community Development Journal,* 42 (3) 2007, pp. 365-378.

Harvey, P.A. and Drouin, T. "The Case for the Rope-Pump in Africa: A comparative performance analysis". *Journal of Water and Health,* 4 (4), 2006, pp. 499-510.

Harvey, P.A. "Borehole Sustainability in Rural Africa: An analysis of routine field data". *Proceedings of 30th WEDC Conference,* Loughborough University, 2004, pp. 339-346.

Harvey, P.A. and Reed, R.A. "Sustainable Supply Chains for Rural Water Supplies in Africa". *Proceedings of the Institution of Civil Engineers: Engineering Sustainability,* 159(1), March 2006, pp. 31-39.